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# CONTENTS

Page

Dr. G. F. W. Müller:

Morphology, Biology and Control of the Hawthorn Spider Mite *Tetranychus viennensis* Zacher *(Acari, Tetranychidae)* . . . . . 1

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BAYER LEVERKUSEN (GERMANY)
Department for Plant Protection

# Morphology, Biology and Control of the Hawthorn Spider Mite *Tetranychus viennensis* Zacher *(Acari, Tetranychidae)*

by Dr. G. F. W. Müller
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CONTENTS

Page

Introduction . . . 2

I. Systematic classification and nomenclature . . . 2

II. Morphology of the different stages of development . . . 3
A. Method . . . 3
B. Females . . . 3
C. Males . . . 13
D. Egg . . . 23
E. Larva and 1st quiescent stage . . . 23
F. Protonymph and 2nd quiescent stage . . . 23
G. Deutonymph and 3rd quiescent stage . . . 23

III. Biology . . . 24
A. Winter quarters . . . 24
B. Overwintering . . . 25
C. Migration of females of *Tetranychus viennensis* from their winter hiding places . . . 26
D. Development and life-cycle of the mites . . . 27
1. Method of studies . . . 27
2. Sequence of generations . . . 27
3. Development of the different stages . . . 31
4. Life-cycle of imagines . . . 34
5. Oviposition of winter and summer females . . . 35
a) Location of oviposition . . . 35
b) Number of eggs laid by winter and summer females; period of oviposition . . . 35
6. Pre-ovipositional and post-ovipositional periods . . . 38
7. Numerical ratio of males to females, parthenogenesis, and number of eggs laid by unfertilized females; mating . . . 39
8. Mortality of the different stages of development in 1953 and 1954 . . . 40
E. Factors governing the occurrence of winter females . . . 42

IV. Epidemiology and ecology . . . 43
A. Weather and change in population density . . . 43
B. Injury . . . 45
C. Plant hosts . . . 47
D. Geographical propagation . . . 48
E. Possibilities of propagation (wind, spreading of mites) . . . 49

V. Control . . . 51
A. In Winter . . . 51
B. In Summer . . . 53
C. Results and conclusions drawn from the trial controls . . . 55

VI. Summary . . . 56
References . . . 58

## Introduction

In fruit growing circles in Germany, it is customary to refer to spider mites as "Rote Spinne" (red spiders), which are understood to be *Metatetranychus ulmi* Koch. It has, however, been established that other spider mite species occur in orchards. Roesler (1951) and Dosse (1953) have reported the incidence of new species in fruit cultures. In his paper, Roesler (1951) mentions *M. ulmi, Bryobia praetiosa* Koch and *Tetranychus viennensis* Zacher as harmful mites occurring on fruit in the Pfalz region, but does not attribute any economic importance to the latter species. In addition to the three species mentioned above, Dosse (1953) refers to the occurrence of *Brevipalpus oudemansi* Geijskes and *Eotetranychus pomi* Sepasgosarian in non-cultivated orchards in Württemberg (Stuttgart-Hohenheim). Data on the biology of *M. ulmi, B. praetiosa, E. pomi* and *Br. oudemansi* are given in the pertinent literature. In respect of *T. viennensis,* however, only the morphology and systematic classification have been dealt with. A precise morphological description of the hawthorn spider mite is lacking, and moreover there are still many questions to be clarified relating to biology, ecology, control measures, change in population density and epidemiology.

*T. viennensis* Zacher is capable of causing serious damage in untreated orchards. Dosse (1954) reports on the occurrence of this mite in Hohenheim, and terms it as a "very noxious species". Its presence has been discovered in many orchards investigated in Württemberg, and has been found to occur in company with *E. pomi.*

The object of this paper is to study the biological and ecological behaviour of *T. viennensis* both under field conditions and in the laboratory with the aim of furnishing data essential for carrying out suitable control measures. An attempt will also be made to clarify outstanding questions appertaining to control dates and suitable insecticides.

## I. Systematic Classification and Nomenclature

Following a careful study of papers published by Zacher (1920), Hirst (1923), Oudemans (1931) and Geijskes (1939), Pritchard and Baker (1955) today classify this spider mite as *Tetranychus viennensis* Zacher. They have placed it in the so-called Viennensis group, as a member of the *Tetranychus* genus, naming the terminal branches of the Peritremae as the characteristic feature.

Synonyms: *Tetranychus (Epitetranychus) viennensis* Zacher
*Tetranychus crataegi* Hirst
*Amphitetranychus viennensis* Oudemans
*Apotetranychus longipenis* Ugarov and Nikolskii

This spider mite was mentioned in the literature for the first time in 1920, both by Zacher (1920) and by Hirst (1920), priority being given to the former.

## II. Morphology of the Different Stages of Development

### A. Method

To carry out thorough morphological examinations of the hawthorn spider mite *T. viennensis*, it is necessary to fix the insects beforehand. This is done by placing the living specimens in a mixture of carbon tetrachloride and alcohol (ratio of 1:1) in order to dissolve out fat and pigment to the greatest possible extent. After 24 hours, the mites are transferred to a vessel containing pure lactic acid to which a solution of direct deep black is added (direct deep black dissolved in 95 % alcohol; 20 to 30 drops of this solution to 20 ccs of pure lactic acid). They are then freed of remaining lipides and pigments in this mixture by carefully boiling for 2 to 3 hours in a water bath. Immediately afterwards, they can be dissected in a drop of lactic acid.

The mites can also be steeped in Faure's solution. It is commendable to support the cover glasses at the corners by means of small cover glass fragments so that the preparations will not be crushed.

To determine their size, the mites were placed alive in Faure's solution, and measured without a cover glass. The distance between the pedipalpus tip and the end of the dorsum was taken for determining the lengths, and the widths were measured at the broadest part of the mite's body (boundary between proterosoma and hysterosoma).

The obtained values were rendered significant by calculation of errors.

### B. Females

The females of *T. viennensis* occur in two forms, namely

1. in the summer form (as summer females), and
2. in the winter form (as winter females).

Both forms are alike morphologically, but they differ in size and in colour.

The length of the mite is given by Hirst (1923) at 0·335 to 0·460 mm, and by Geijskes (1939) at up to 0·740 mm. The publication of Ugarov and Nikolski (1937) was only accessible in the work of Pritchard and Baker. Measurements of width are not known from the literature. The data given in respect of the above lengths do not indicate whether they apply to the summer or winter form. It is, however, most striking that the size of the female fluctuates considerably. This is confirmed by my own measurements.

*Table 1:* Length and breadth of females

| | Length in mm | Breadth in mm | Ratio of length: breadth | No. of insects |
|---|---|---|---|---|
| Freshly emerged imagines | 0·520 ± 0·013 | 0·306 ± 0·012 | 1 : 0·58 | 20 |
| Summer females in process of egg-laying | 0·675 ± 0·011 | 0·411 ± 0·003 | 1 : 0·61 | 30 |
| Winter females | 0·368 ± 0·004 | 0·244 ± 0·003 | 1 : 0·66 | 50 |

The lengths and breadths of 20 freshly emerged imagines were measured, giving an average length of $0{\cdot}520 \pm 0{\cdot}013$ mm and an average breadth of $0{\cdot}306 \pm 0{\cdot}012$ mm. Summer females in the process of egg-laying are larger in size than young imagines.

The length of the summer females varies between 0·617 and 0·705 mm, and the breadth between 0·396 and 0·423 mm. During winter dormancy, the winter females are considerably smaller than the summer females although in Spring, when they start to lay eggs, they are just as large as the summer females.

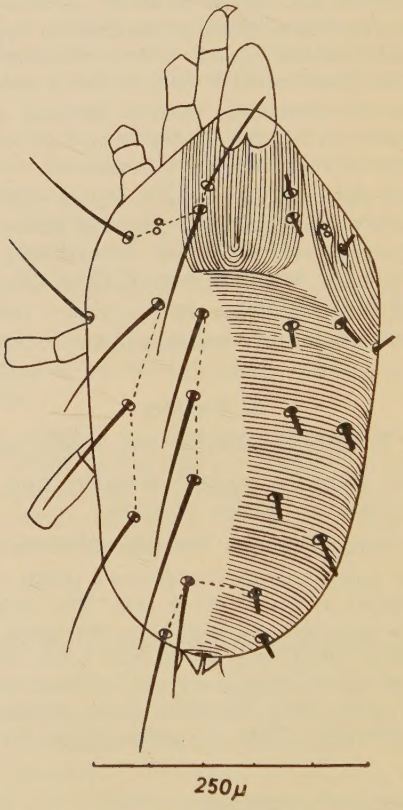


Fig. 1: ♀ dorsal, location of the dorsal tactiles and structure of the skin surface

The skin structure of the females is marked over the entire upper surface with very fine stripes which in the main run in a crosswise direction (Fig. 1). This striping is the result of indentation which in a lateral view is perceptible as a very finely pronounced wavy line. A definite boundary between the hysterosoma and the proterosoma is not to be found on the dorsal side of the mite's body although this boundary exists at approximately the point where the longitudinal striping begins, which forms the "pseudo scale" described by O u d e m a n s (1931). The entire hysterosoma is covered by the cross

striation which curves away slightly in a lateral direction towards the end of the abdomen. The proterosoma, on the other hand, has a more striking skin structure. Here, the U-shaped striping, mainly running in a lengthwise direction, forms the aforementioned pseudo scale. At the side of the scale, there is also longitudinal striping which swings away laterally and curls around the eyes showing them up as small islands. The stripes and groins are smooth, uninterrupted and run alongside each other at equal distances. Ventrally, the skin structure of the female is covered almost exclusively by cross striping which at the side doubles back slightly to the rear. It is only in the genital section that there is a mixture of longitudinal and cross striping.

The striping of the skin is also perceptible on the different members of the extremities although not so well pronounced as on the integument of the body. The stripes do not appear to run in a definite direction or form a regular pattern.

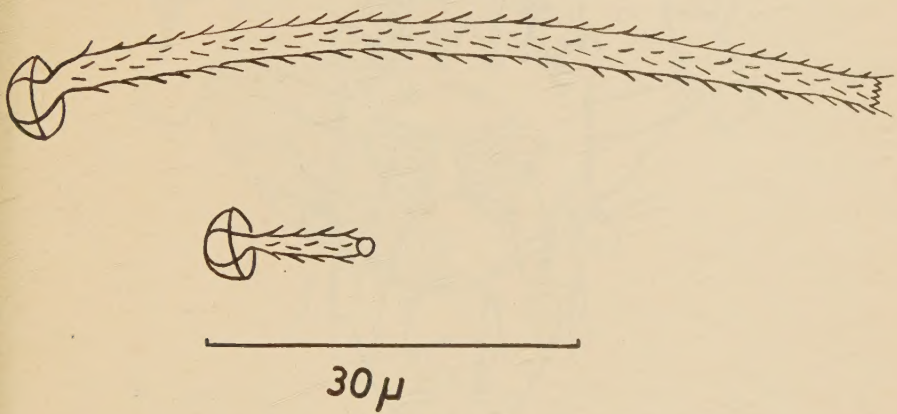


Fig. 2: Dorsal tactile (Sacrales) of a female; secondary hairs (bearing pubescence)

The covering of tactiles on the dorsal and the ventral sides varies considerably. Zacher (1921) and Geijskes (1939) mention that there are 6 cross rows of dorsal tactiles. Pritchard and Baker (1955) have drawn up a new system of notation for the dorsal tactile covering of the *Tetranychus* genus, which gives the following data for *T. viennensis:*

| | |
|---|---|
| Setae dorsales propodosomales | 6 |
| Setae humerales | 2 |
| Setae dorsocentrales hysterosomales | 6 |
| Setae dorsolaterales hysterosomales | 6 |
| Setae sacrales | 4 |
| Setae clunales | lacking |
| Setae posterior paraanales (Postanales) | 2 |

This gives a total of 26 dorsal setae.

All the dorsal hairs, with the exception of the Postanales, are round and well developed. Their proximal, globular ends are located in cuplike depressions set in the skin. Very fine secondary hairs are to be found over the entire

tactile surface (Fig. 2). All the dorsal tactiles point to the rear in a slightly lateral direction, and they overtower each following hair by approximately one-third of their length. The two Setae humerales which are set practically vertical to the longitudinal axis, and the foremost hair of the Setae dorsales propodosomales, which points in a forward direction, are exceptions.

The description of the ventral tactile covering (Fig. 3) includes the hair covering of the Coxae. Coxae I and II each have two tactiles, with the outer one pointing outwards and the inner one pointing inwards. Coxae III and IV each have a tactile pointing inwards. On the mite body itself, there is a pair

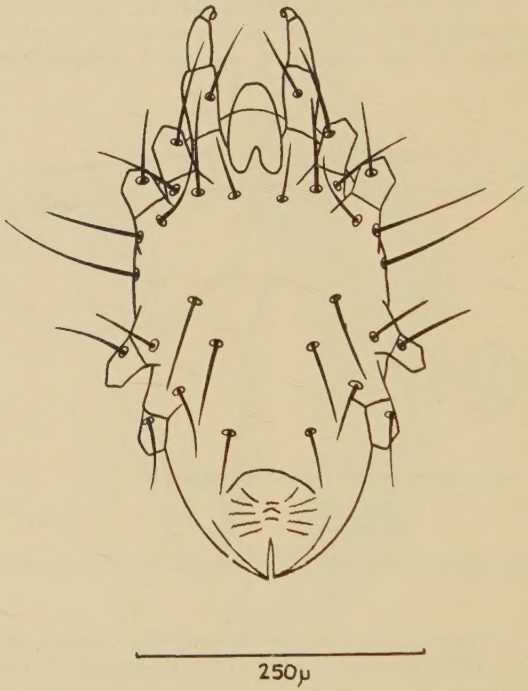


Fig. 3: ♀ ventral

of tactiles pointing forwards, located between the two Coxae I. Three other pairs of setae are to be found in the metapodosoma, pointing to the rear; one pair each between Coxae III and IV, and one below the boundary between the metapodosoma and the opisthosoma. A pair of bristles is located on the side of the genital plate, pointing to the front. The sides of the genital section (Fig. 4) are flanked by two tactiles. Two other tactiles, the anterior paraanales, do not belong to the genital section, but are located away to the side of it, while at the distal end of the anus there are two small tactiles — the anales — located as a pair.

18 tactiles are located on the underside of the body; in addition to these are 12 from Coxae I to IV, giving a total of 30 tactiles.

All six segments of the legs carry, in various ways, hairs or tactiles which are taken into consideration for the morphological and systematic determination. In particular, the number, length, shape and location of the tactiles on the tarsus and tibia, and also the development of the ambulacral apparatus are of importance for the systematic classification.

Pritchard and Baker (1955) quote two main groups of bristles in respect of *Tetranychidae:*

1. Tactiles
2. Chemosensory setae

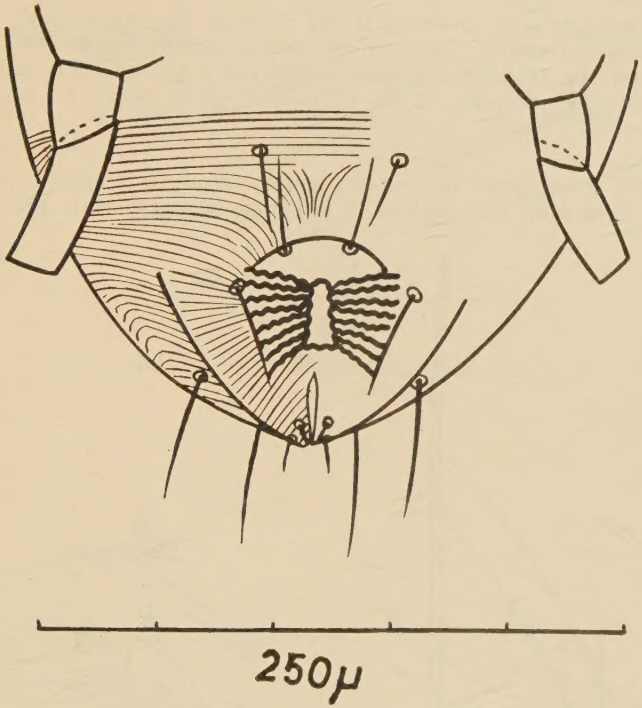


Fig. 4: ♀ Genital section

The chemosensory setae described by Pritchard and Baker (1955) are to be found on the extremities of *T. viennensis,* and can be subdivided into four different forms (Figs. 5 and 8).

1. Chemosensory setae which mostly are short, moderately to heavily curved, thinly walled, and rounded off at their distal end; basal ring at the proximal end, and consequently not globularly located.
   They have a very fine wavy surface, and when closely inspected, cross shading can be recognized.
2. Very long chemosensory setae, each located with a short, slender seta in a non-subdivided double ring. The long hair is not guided in a basal

ring, and runs out in a most slender manner, although it is perceived to have a rounded-off end. These long chemosensory setae have a smooth surface.

3. Chemosensory setae located on a small protuberance on the ambulacrum, with a smooth surface, and likewise not guided. These setae appear not to be shaded, and have a thick wall. Their distal end is rounded off.
4. Very fine, thinly walled setae which widen out in unifundibular form (knob-ended) at the distal end. These setae are located on the empodium, and arise in pairs out of a common base.

Pritchard and Baker (1955) provide an illustration of tarsus I and II and tibia I and II. The number, length and arrangement of the tactiles and setae on the Hohenheim species conform with the illustration of these authors, with the exception of the differences given below for tarsus I.

*Tarsus I:*

Tarsus I is equipped with chemosensory setae in a special manner. Out of a total of 18 setae and tactiles, 6 are chemosensory setae. The two double

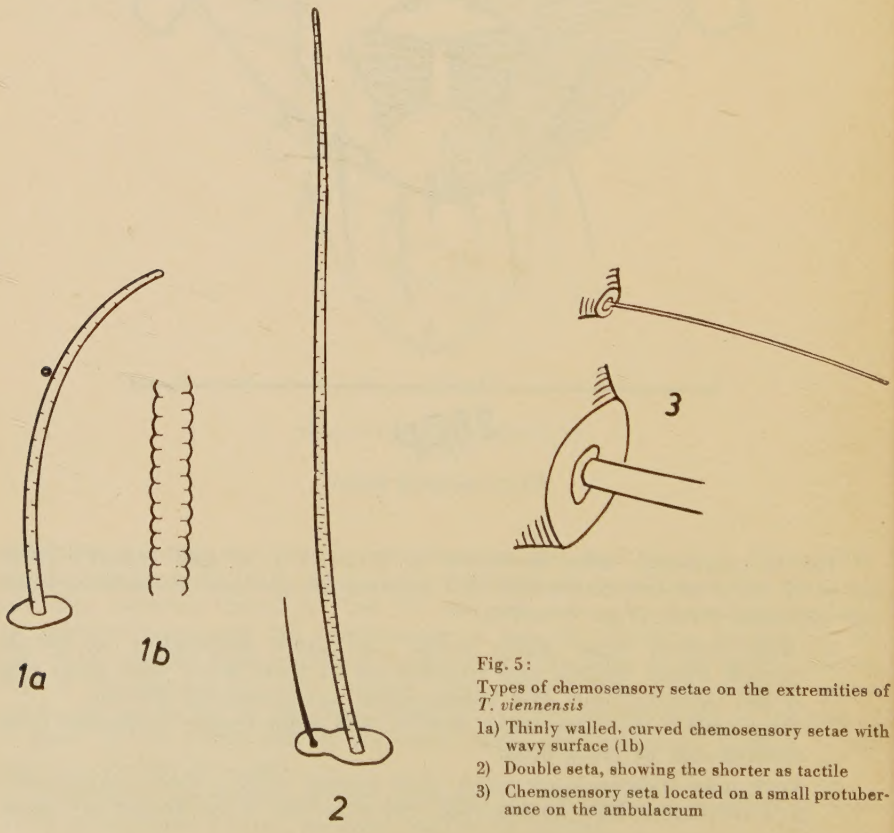


Fig. 5:
Types of chemosensory setae on the extremities of *T. viennensis*
1a) Thinly walled, curved chemosensory setae with wavy surface (1b)
2) Double seta, showing the shorter as tactile
3) Chemosensory seta located on a small protuberance on the ambulacrum

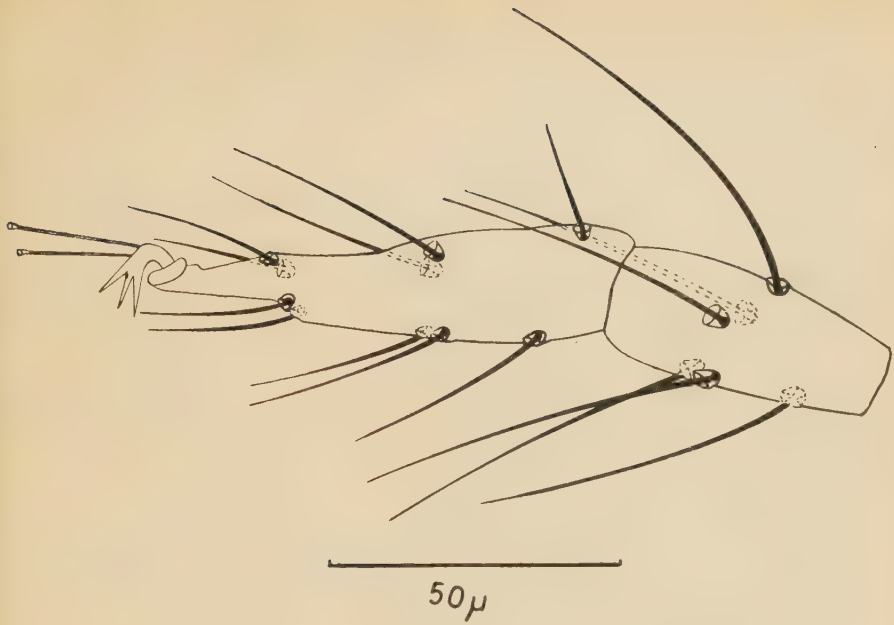


Fig. 6: Tarsus and tibia III ♀ (ambulacrum and empodium halved)

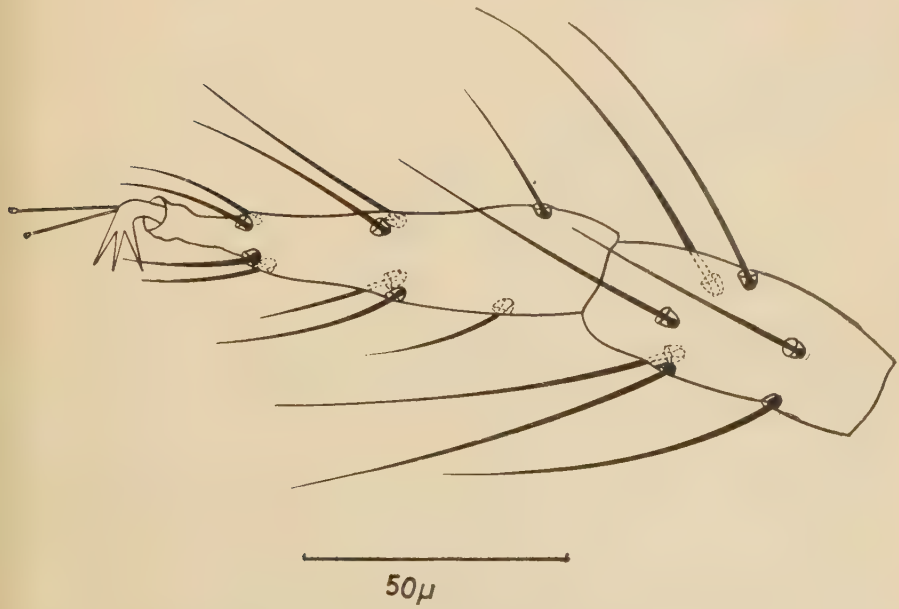


Fig. 7: Tarsus and tibia IV ♀ (ambulacrum and empodium halved)

setae on the dorsal side are located, however, in a common ring which is not subdivided. — Pritchard and Baker (1955) show a transverse wall, and the serration of the spur is approximately one-third longer than that on tarsi II, III and IV (Pritchard and Baker [1955] show the same spur serration for tarsus I and II).

*Tibia I:*

There are a total of 10 hairs on tibia I, and of these only one is a chemosensory seta. It is located in the front third section, and points upwards.

*Tarsus II:*

Tarsus II is covered with 15 hairs, of which 5 are chemosensory setae. In contrast to tarsus 1, it only has one double hair located in the centre of the dorsal side, analogous to the two double hairs of tarsus I.

*Tibia II:*

Tibia II is covered with a total of 6 ordinary tactiles which are all more or less of the same length and thickness.

*Tarsus III and IV* (Figs. 6 and 7):

Altogether, there are ten ordinary tactiles on tarsus III. There are no chemosensory setae underneath. One dorsal tactile close to the tibia is approximately half the size of the others which are distributed almost symmetrically over the entire tarsus. Tarsus IV does not differ from tarsus III. It is also covered with ten tactiles arranged in the same manner, and has no chemosensory setae.

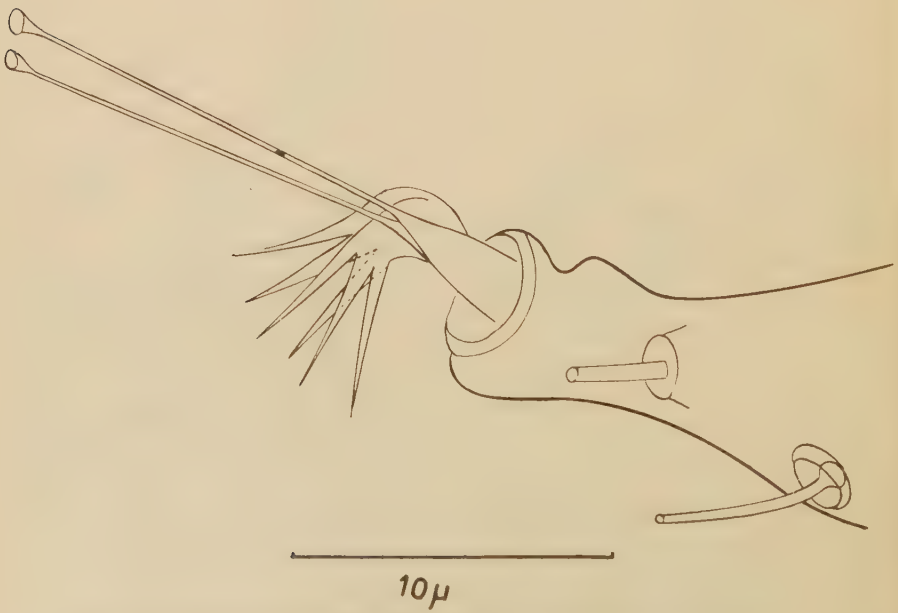


Fig. 8: Ambulacrum and empodium of tarsus I ♀ (ambulacrum shown only on one side)

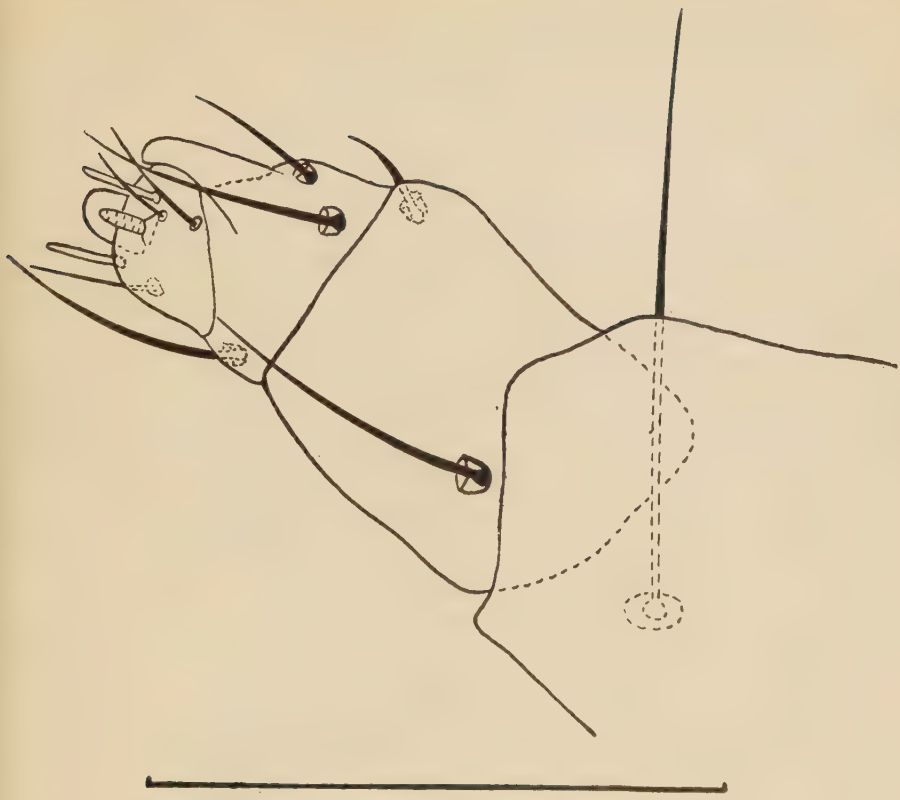


Fig. 9: Pedipalpus ♀

*Tibia III and IV* (Figs. 6 and 7):

There are 6 tactiles and no chemosensory setae on tibia III. In the centre of the dorsal side, there is a long and strongly developed hair. There are no chemosensory setae present on tibia IV either, although in contrast to tibia III another hair is located at the side on the last third-section of the segment.

A study of a large number of mites did not reveal any differences and fluctuations in the tactile and setae covering.

*Ambulacrum and empodium* (Fig. 8):

The ambulacral spurs originally present on mites are modified on *T. viennensis*. In each case, the outer spur has been transformed into a short, thick bacillus which splits and forms two adhesive hairs. The four adhesive hairs formed on one base each have a unifundibular expansion at the distal end.

The empodium located between the bacilli splits at the point of curvature, and ends in each case in three very fine, small pointed teeth.

The empodiums and ambulacral appendages of tarsi I to IV are isomorphous. The serration on the empodiums of tarsi I is approximately one-third longer than that of tarsi II, III and IV.

*Pedipalpi* (Fig. 9):

There are 7 modified hairs on the palptarsus. The number, location and arrangement conform with the illustrations of Hirst (1923) and Pritchard and Baker (1955). Three of these hairs are slender, short, slightly curved, and guided with a basal ring. In his illustration, Hirst (1923) shows one hair located close to the terminal butt to be longer than the other two. On the Hohenheim species, however, all the ordinary hairs on the palptarsus are more or less of equal length and thickness. Two modified hairs are slightly longer than wide (ratio 1·2:1), and on a small protuberance there is a tiny spindle which appears to be cross-shaded. Two thick, non-shaded tactiles are to be found between the terminal butt and the spindle.

Apart from three tactiles, the palptibia possesses a claw, the end of which is curved towards the tarsus. Two guided tactiles are located on the palpfemur, one being ventral and very long, the other lateral and short. Dorsally, the trochanter possesses a very long, thick and guided hair.

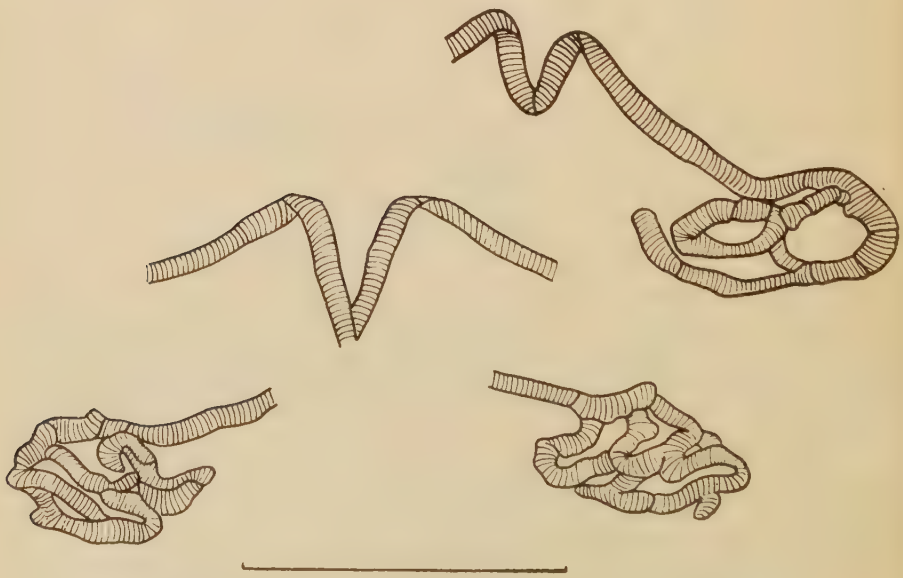


Fig. 10: Peritrema ♀

*Peritrema* (Fig. 10):

Zacher (1949), Geijskes (1939) and Pritchard and Baker (1955) have provided in their papers, illustrations of the peritremae of *T. viennensis*. Zacher found that the tracheal trunks are subdivided in the same manner as the terminal branchings. Geijskes (1939) observed a needle-shaped apophysis at the branched terminal part of the peritremae. Neither the observation of Zacher nor that of Geijskes could be confirmed on the studied preparations of the Hohenheim species. All the illustrations of the above-mentioned authors vary. My own observations correspond mainly to those described by Pritchard and Baker (1955).

The peritremae can be divided into a main branch and a convolution of terminal branches, anastomoses.

Both the main branch and the twined terminal branches appear to be strengthened by rings. In a normal position, the main branch first of all runs in a forward direction at an angle of approximately 30 degrees to the longitudinal axis, and about half-way down its entire length it then curves to the side by about 90 degrees, terminating in the anastomoses which form compartments among themselves.

It may bulge out slightly close to its source (in approximately half of the specimens examined). A definite form of the end part is never to be found.

### C. Males

Hirst (1923) is the only author who has so far given a brief description of the male. The data are, however, inexact so that special attention has been paid in these studies to the morphology of the male.

The male can be distinguished from the female without difficulty due to its characteristic shape. It is smaller, slimmer and pointed towards the end of the dorsum. In contrast to the female, the broadest part of the male is close to the base of the third pair of legs.

The colour of the male varies. Shortly after emerging out of the third quiescent stage, it is sulphur-yellow but soon changes to dark yellow and then to sandy-yellow. Chlorophyll intercalations can be seen quite clearly in the form of greenish-black spots under the integument. As the male grows older, these intercalations become black. In Spring, the young male appears more greenish-yellow in the proterosoma whereas the colour of the hysterosoma is as described above. The colour of the integument on older males changes, the primary sandy tone remains, although brown spots appear on the surface of the skin. The sides of the male are not wavy like those of the female, but are ductile as far as the abdomen. The males appear during the vegetation period from Spring to late Autumn. There are only Summer types.

*Table 2:* Length and breadth of male.

| Length in mm | Breadth in mm | Ratio of length : breadth | No. of insects |
|---|---|---|---|
| 0·402 ± 0·004 | 0·191 ± 0·007 | 1 : 0·48 | 30 |

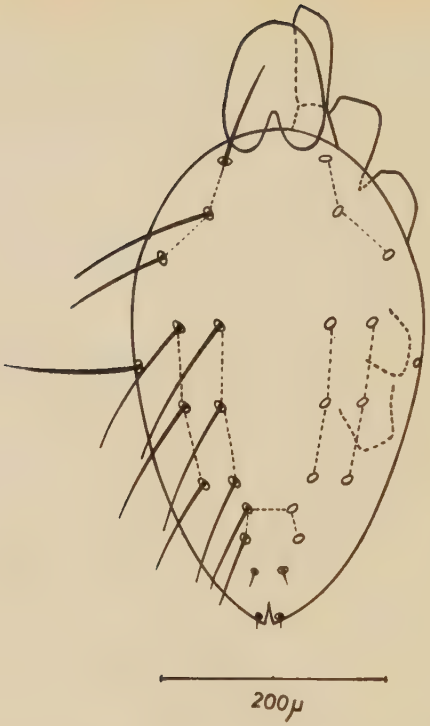


Fig. 11:
♂ dorsal.
Arrangement of dorsal tactiles

The size of the males, just like that of the females, varies considerably. The minimum length and breadth measured were 0·325 mm and 0·176 mm respectively; maximum length of 0·468 mm, and maximum breadth of 0·208 mm.

Like the female, the skin of the male is marked by very fine stripes although they are not pronounced to the same extent as on the female. The dorsal side is covered with transverse stripes. In the propodosoma, the "pseudo scale" described in respect of the female, is formed by longitudinal stripes. The entire length of the ventral side is covered by transverse stripes. At the side, the transverse striping curves away slightly to the rear, being particularly noticeable at the anal slit so that the impression is created that the stripes are running in a longitudinal direction (Fig. 13). Large transverse folds begin to form behind the base of the fourth pair of legs, permitting the dorsum to be curved upwards during copulation. The two double eyes are no different in their shape and construction from those of the female. They are outstanding in the male due to red pigmentation.

The number of dorsal tactiles on the male is the same as on the female (Fig. 11). The arrangement differs at the tip of the dorsum where the two post-anales are located farther forwards on the male. In comparison with the female, there are more hairs on the ventral side. Between coxae I, there is a pair of hairs pointing in a forward direction. There is also one pair between coxae II and another pair between coxae IV, which means that in the propodosoma there is one pair and in the metapodosoma two pairs.

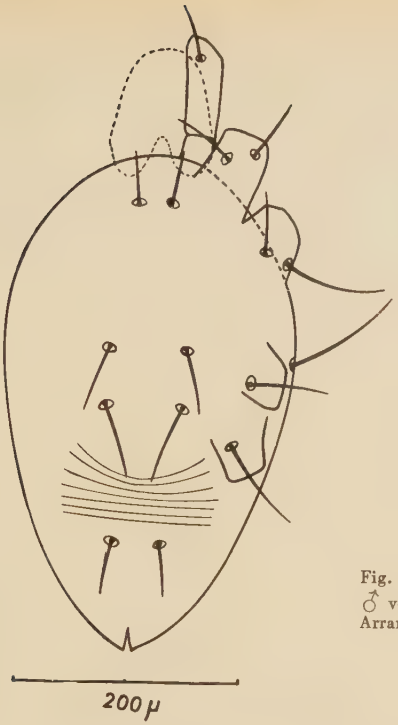


Fig. 12:
♂ ventral.
Arrangement of ventral tactiles

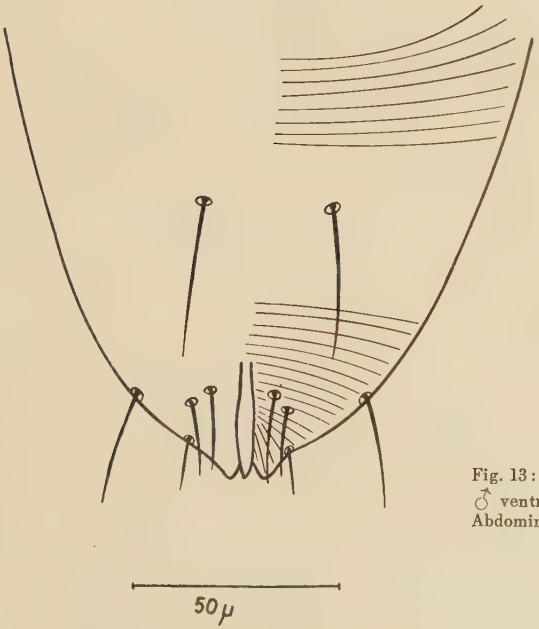


Fig. 13:
♂ ventral.
Abdominal tactile covering

The tactile covering in the opisthosoma does not correspond to the abdominal tactile covering usually applicable to *Tetranychus*. Pritchard and Baker (1955) quote as the characteristic of the subfamily *Tetranychinae*, four pairs of genital-anal setae for the male and two pairs of anal setae for the female.

Two hairs are situated behind the skin wrinkles beginning at coxae III (Figs. 12 and 13). Then follow two pairs of anales setae which belong to the dorsum tip and are located on both sides of the anal slit. There is a further pair of anal hairs to be found at the side of the dorsum tip on the male.

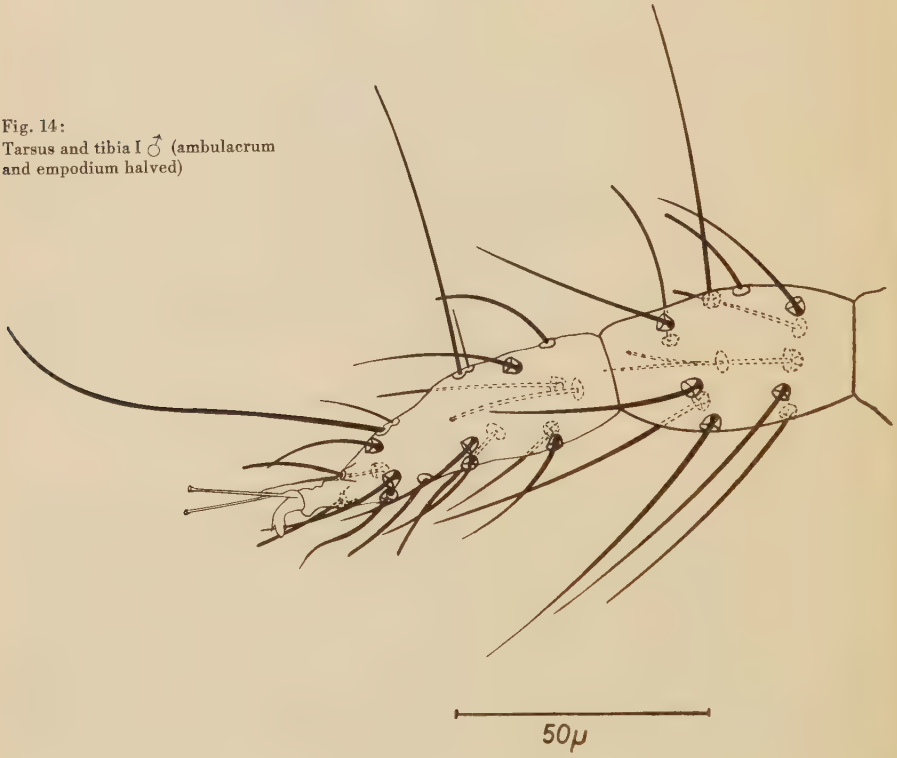


Fig. 14:
Tarsus and tibia I ♂ (ambulacrum and empodium halved)

The fourth pair of anal hairs is wanting. Consequently, the male has six anal setae. The outer sides of the abdominal apex are flanked by a pair of setae which are termed as para-anales setae analogous to the abdominal hair covering of the female. Altogether, there are 16 hairs on the underside of the male body.

The tactile covering of coxae I to IV is the same as that on the female, in other words 12 tactiles are also located in this section so that there is a total of 28 tactiles on the ventral side including those of the coxae.

The segments of the male are all longer than those of the female.

*Tarsus I* (Fig. 14):

With regard to the hair covering, the tarsus I of the male differs from that of the female in the number of chemosensory setae present. There is a total of 20 hairs on the male tarsus I. Eight of these are chemosensory setae. These are located as follows: one chemosensory seta each situated on a small protuberance left and right of the ambulacral appendages, another one on the ventral side in the first third-section, laterally two chemosensory setae — one more or less in the centre, the other in the last quarter of the tarsus — and one chemosensory seta on the dorsal side in the last quarter of the tarsus. Just as on the female, there are two double hairs on the dorsal side on tarsus I of the male (Fig. 14); the longer hair is referred to as a chemosensory seta. The 12 ordinary tactiles are distributed over the whole of the tarsus, but the majority of them point, ventrally, in a forward direction.

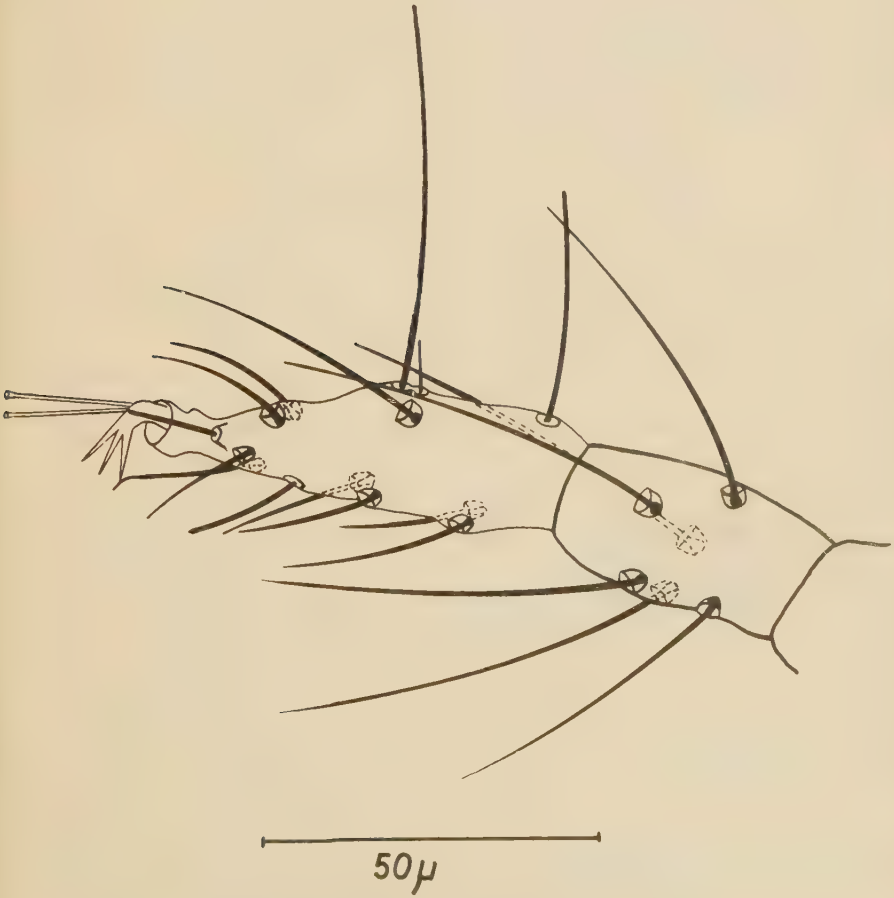


Fig. 15: Tarsus and tibia II ♂ (ambulacrum and empodium halved)

*Tibia I* (Fig. 14):

The hair covering on tibia I of the male also differs from that of the female. Altogether, there are 13 hairs, four of which are chemosensory setae. Two of these are located laterally in the last quarter and two are on the dorsal side pointing forwards and upwards, respectively; of the latter, one is in the centre and the other at a slightly lower point in the first third-section of the tibia. Nine ordinary tactiles are distributed over the entire segment, the majority being located on the ventral side. The ordinary tactiles on tibia I are stronger and longer than those on tarsus I.

*Tarsus II* (Fig. 15):

There are altogether 15 hairs on tarsus II, and of these five are chemosensory setae. On the dorsal side there are two — one double hair in the centre, and one shaded chemosensory seta in the last quarter of the tarsus. There is also a chemosensory seta seated on a small protuberance at each side (left and right) of the ambulacral appendages. One chemosensory seta is to be found on the underside of the tarsus in the first third-section. Ten tactiles are distributed over the whole of the tarsus II, the majority of these being on the ventral side and pointing in a forward direction. These hairs are arranged symmetrically on the underside of the tarsus.

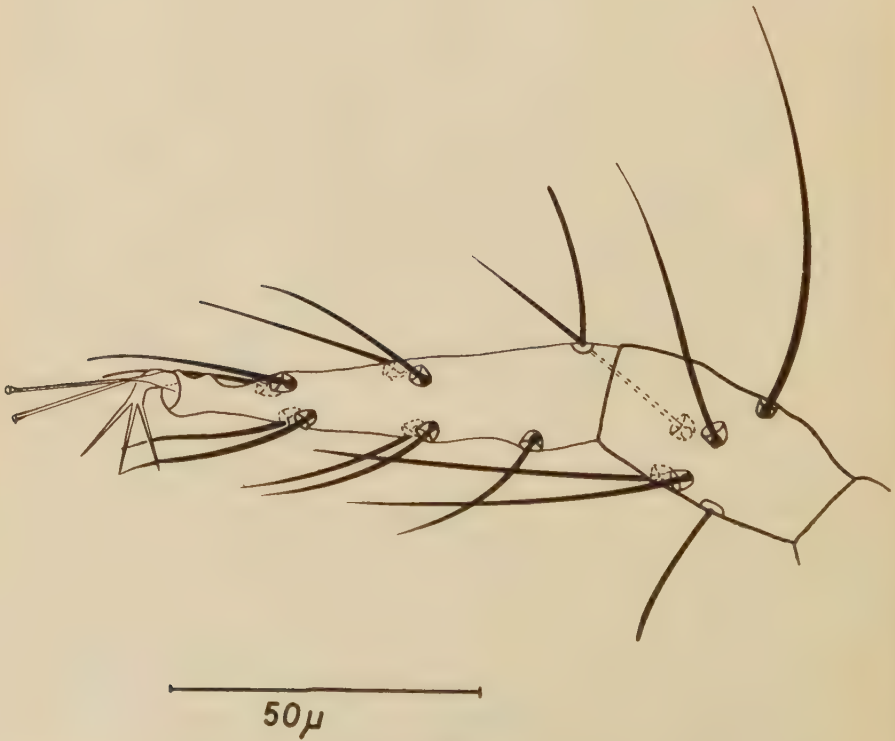


Fig. 16: Tarsus and tibia III ♂ (ambulacrum and empodium halved)

The only difference as compared with tarsus II of the female is that tarsus II of the male has one chemosensory seta more.

*Tibia II* (Fig. 15)

Tibia II possesses the same number of tactiles as tibia II of the female; altogether, there are six strong hairs spread out over the whole of the tibia.

*Tarsus III* (Fig. 16):

There are 10 hairs on tarsus III, including one chemosensory seta on the dorsal side in the last quarter. The presence of this chemosensory seta constitutes the only difference between tarsus III of the male and that of the female. All the ordinary hairs are arranged symmetrically on the dorsal and the ventral sides with the exception of one ordinary tactile located ventrally in the last third-section.

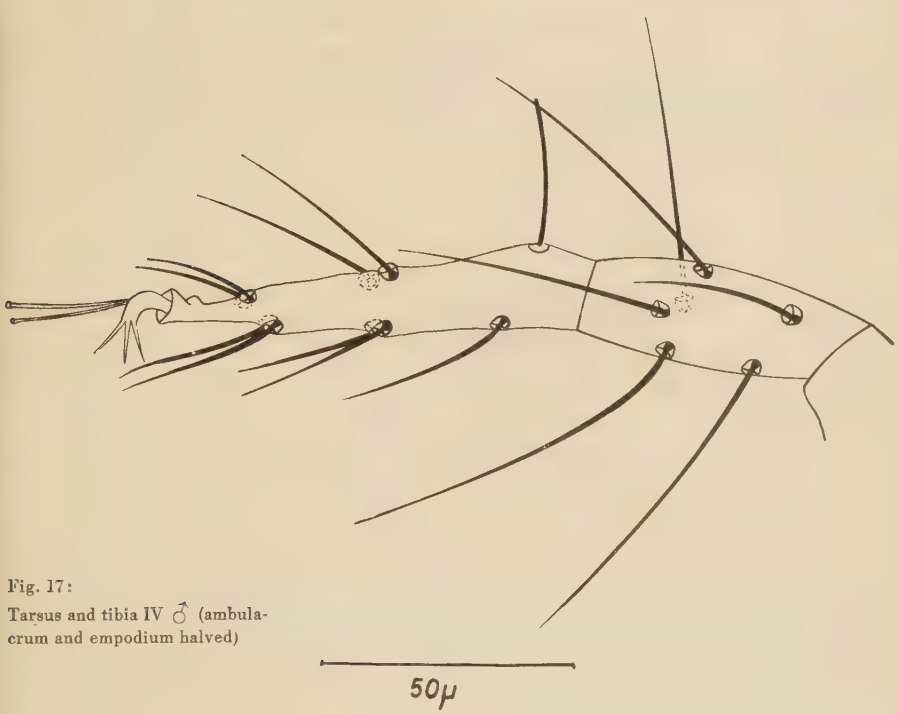


Fig. 17:
Tarsus and tibia IV ♂ (ambulacrum and empodium halved)

*Tibia III* (Fig. 16):

Just like the female, tibia III of the male also has six tactiles. One hair is modified as a chemosensory seta, and is located on the ventral side more or less in the centre. The ordinary hairs are strongly developed and long.

*Tarsus and Tibia IV* (Fig. 17):

The number and arrangement of the hairs on tarsus IV of the male, are the same as for tarsus III. There are six strong and long ordinary hairs on tibia IV. A chemosensory seta is wanting.

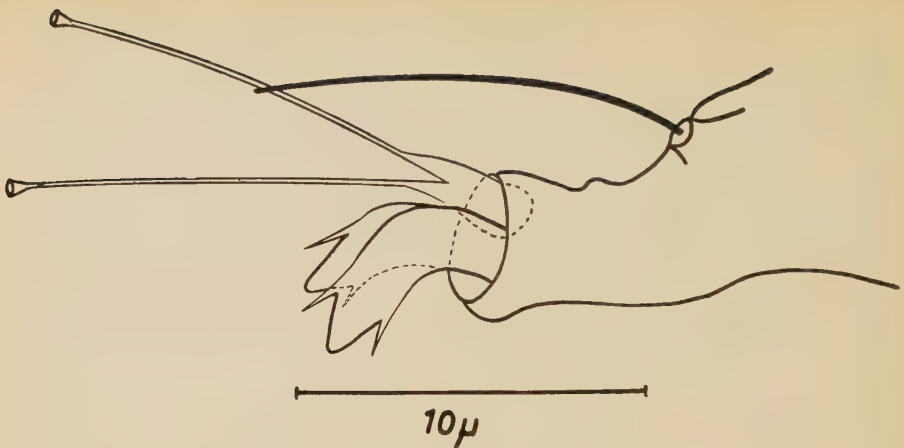


Fig. 18: Ambulacrum (halved) and empodium lateral on tarsus I, ♂

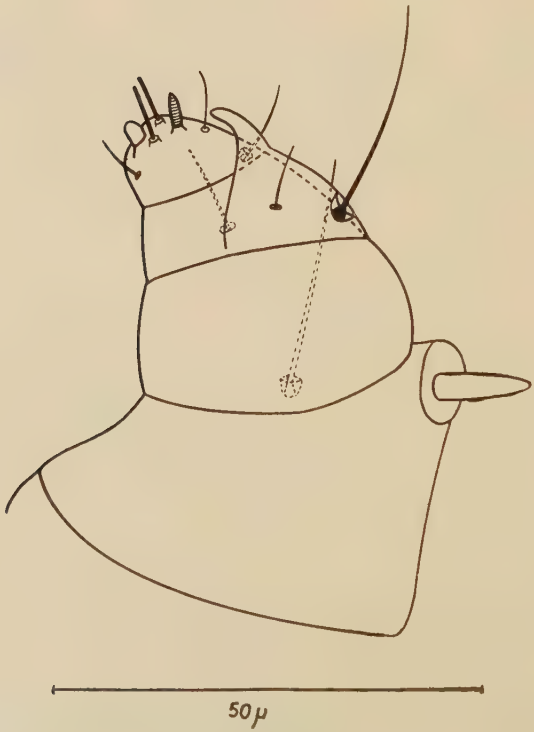


Fig. 19: Pedipalpus ♂

The ambulacrum and empodium of the male — the tarsus appendage systems — do not completely correspond to those of the female. The ambulacral appendages, admittedly, are identical with those of the female but there are differences between the empodiums.

On the empodium of tarsus I of the male (Fig. 18), the centre apophysis of the three-part claw is in each case very strongly developed whereas at the side of it, only two very fine, small rudimentary teeth are to be established for the two remaining apophyses. The appendage structures of tarsi II, III and IV have a split empodium. Both halves of the claw each terminate in three very fine small teeth. They are constructed similarly to those of the female.

The pedipalpi (Fig. 19) of the male differ but very little from those of the female.

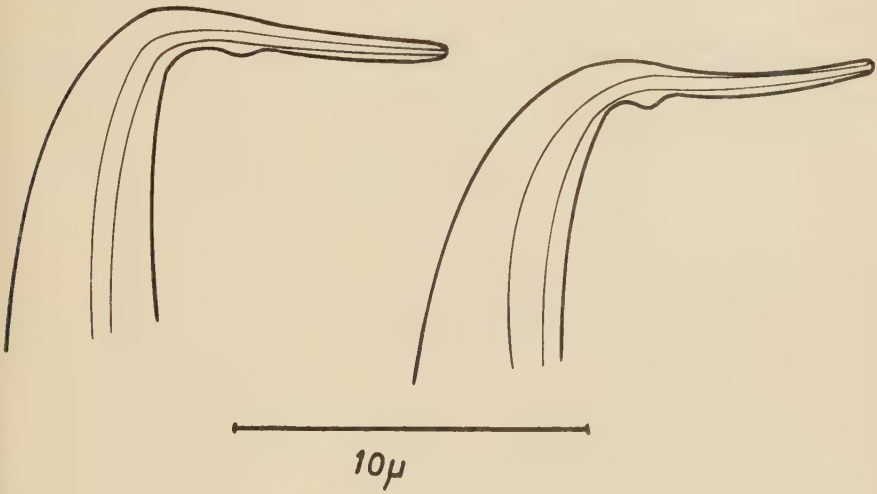


Fig. 20: Penis forms

The appendage structures described in respect of the female are to be found in the same form and number on the palptarsus, with the exception of the sensory butt which on the male is considerably smaller and narrower (length : breadth ratio of 1:1·4). As on the female, the palptibia of the male has three tactiles (Hirst [1923] only shows two tactiles in his illustration), one of which is strongly developed. The palpfemur has only one simple hair. A well-developed pin-shaped sense organ situated on a ring-shaped elevation is to be found on the outside of the palptrochanter close to the palpfemur. The ordinary hair present on the female is wanting on the male.

The male peritremae are very similar to those of the female although somewhat smaller in their structure. The anastomoses have more subdivisions on the male so that the different sections are smaller.

The penis (Fig. 20) of *T. viennensis* differs considerably from that of other *Tetranychidae*. Zacher (1921) provides an illustration in his publication, according to which the penis of *T. viennensis* possesses a long, thinly

drawn-out clasper which has a small bulge at its basis just before the point where there is a bend on the shaft. The shaft is well developed; a basallobus is not developed to any mentionable extent, in contradiction to Zacher's illustration. A barb is completely wanting. A tube runs from the stem to the foremost tip of the clasper. Hirst (1923) describes the penis, and refers to a small knot at the proximal end, in which he presumes the barb is present. This small knot was observed in all cases on the penis of the Hohenheim species. The form of the penis on the Hohenheim species conforms with that shown in Hirst's (1923) illustration.

*Table 3:* Lengths and breadths of the juvenile and quiescent stages (average values expressed in mm).

| | Average | | | After hatching | | | Prior to quiescent stage | | |
|---|---|---|---|---|---|---|---|---|---|
| | Length | Breadth | Ratio of length: breadth | Length | Breadth | Ratio of length: breadth | Length | Breadth | Ratio of length: breadth |
| Larva | 0·208 ± 0·0055 | 0·145 ± 0·0031 | 1:0·69 | 0·191 ± 0·0042 | 0·135 ± 0·0023 | 1:0·71 | 0·234 ± 0·0028 | 0·159 ± 0·0026 | 1:0·68 |
| 1st quiescent stage | 0·271 ± 0·0062 | 0·172 ± 0·0042 | 1:0·63 | — | — | — | — | — | — |
| Protonymph | 0·279 ± 0·0058 | 0·171 ± 0·0029 | 1:0·61 | 0·258 ± 0·0045 | 0·161 ± 0·0026 | 1:0·62 | 0·302 ± 0·0041 | 0·184 ± 0·0032 | 1:0·60 |
| 2nd quiescent stage | 0·400 ± 0·01 | 0·244 ± 0·0072 | 1:0·61 | — | — | — | — | — | — |
| Female deutonymph | 0·448 ± 0·0081 | 0·268 ± 0·0065 | 1:0·60 | 0·407 ± 0·0018 | 0·242 ± 0·0027 | 1:0·60 | 0·475 ± 0·0051 | 0·294 ± 0·0048 | 1:0·61 |
| 3rd female quiescent stage | 0·479 ± 0·0089 | 0·279 ± 0·0079 | 1:0·55 | — | — | — | — | — | — |
| Male deutonymph | 0·336 ± 0·0097 | 0·195 ± 0·0062 | 1:0·58 | 0·292 ± 0·0059 | 0·167 ± 0·0024 | 1:0·57 | 0·372 ± 0·0037 | 0·217 ± 0·0039 | 1:0·58 |
| 3rd male quiescent stage | 0·417 ± 0·0071 | 0·182 ± 0·0043 | 1:0·48 | — | — | — | | — | — |

### D. Egg

The eggs of *T. viennensis* are spherical, and shortly after oviposition bright and slightly whitish with a glassy shimmer. The egg surface has no outstanding structure, and is smooth. 90 measurements showed the diameter of the egg to be 0·145 ± 0·0003 mm on the average.

### E. Larva and 1st quiescent stage

Twenty to thirty measurements were taken on the average for each development stage of *T. viennensis*. The increase in length and breadth following each ecdysis is shown in Table 3. The ratio of length to breadth changes from an average of 1 : 0·69 for the larva to 1 : 0·58 and 1 : 0·48 for the female and male imagines, respectively.

The six-legged larva is still round shortly after hatching out, but very quickly loses its roundish shape due to immediate consumption of food, and becomes oval. On the average, the length of the larva is 0·208 ± 0·0055 mm, and the breadth 0·145 ± 0·0031 mm.

Measurements of length and breadth taken shortly after hatching give values of 0·191 ± 0·0042 mm and 0·135 ± 0·0023 mm, respectively, whereas just prior to the first quiescent stage the larvae grow to a length of 0·234 ± 0·0028 mm and a breadth of 0·159 ± 0·0026 mm.

Length : breadth ratio: a) shortly after hatching 1 : 0·71
b) prior to 1st quiescent stage 1 : 0·68
c) on the average 1 : 0·69

The larval period is followed immediately by the first quiescent stage (Table 3).

### F. Protonymph and 2nd quiescent stage

The body-form in the protonymphal stage (Table 3) is oval. In comparison with the larval stage, the protonymph has one pair of legs more, and longer dorsal tactiles. The sexual dimorphism is not recognizable in the protonymphal stage. It was observed that the protonymphs produced web fibres, which means that they already possess spinning glands.

The protonymphal stage is followed by the 2nd quiescent stage (Table 3).

### G. Deutonymph and 3rd quiescent stage

A large number of observations confirm the data given by Gasser (1951) and Andersen (1947), in contradiction to Zacher (1920) and other authors, that not only females but also males pass through the second nymphal stage and the third quiescent stage. Sexual dimorphism is perceptible for the first time in the deutonymphal stage. Generally, a female deutonymph (Table 3) has the form of the female imago whereas the male deutonymphs (Table 3) already have a pointed abdomen. Gasser (1951) established that *T. urticae* copulates in the deutonymph stage but this was not observed for the *T. viennensis* although deutonymphs were often surrounded by several males. The greatest increase in size is to be found among the female deutonymphs.

Towards the end of their feeding period, they almost attain the size of the prosopa.

The third quiescent stage constitutes the end of the juvenile development (Table 3).

The position of the different quiescent stages of *T. viennensis* does not differ from those of other *Tetranychidae*.

## III. Biology

All data so far published in the literature on the hawthorn spider mite are based on morphological and systematic studies. Hardly any information has been furnished to date on the biology of this species.

For this reason, the chief attention has been concentrated in these studies on the biological behaviour of this mite. Greater significance was attributed to the field studies, and — insofar as necessary — part questions were clarified in laboratory tests. Partial studies on the overwintering of the species, its dependence upon temperature and relative humidity and its migration from the winter quarters preceded the investigations on the development and life of the mite.

### A. Winter quarters

Only the females overwinter; the males die off before the cold season sets in.

Between 1952 and 1954, a search was conducted in the surroundings of Stuttgart-Hohenheim and in the district of Nürtingen/Neckar to find the females in their winter quarters on fruit trees (chiefly apples but also pears, plums and damsons). It was established that the females overwinter on the plant host itself. The insects do not retreat to parts of the plant growing under the ground but hide in protected places, under pieces of bark, mosses or lichens. Loose bark is always to be found on the bases and forks of boughs and branches on a young fruit tree, and it is under this bark that the winter females go into dormancy, often in large numbers. They may also be found particularly at the base of larger water shoots on old boughs.

The distribution of the winter quarters on a tree is likewise characteristic. On a standard tree, they are to be found scattered over the whole of the crown but not on the trunk.

In addition to the overwintering locations given above for the Hohenheim form of *T. viennensis*, Rambier (1954) also speaks of the Mediterranean form having hiding places in the soil, chiefly in hollows and crevices close to the tree. It must be assumed that the Mediterranean species has adapted itself in its manner of overwintering to the subtropical climate of the French Mediterranean region. The Hohenheim species was never discovered in or on the soil, or on the flora in the vicinity of a tree.

The position of the winter quarters at the points mentioned is again characteristic of the species. On a young fruit tree, the females do not settle under the dead parts of the bark but they show a preference for small cavities between the epidermis and the dead bark where they spin a web around themselves. The web is not very thick so that it can hardly be said to protect

the mites against the cold. On the contrary it must be assumed that the web is designed to hold in position the females which become stiff due to the cold, and perhaps to make it difficult for pursuers to penetrate into an overwintering quarter. In the winter quarter itself, the females are to be found most distributed over a relatively large area so that they are seated singly but close to one another, on a base.

A maximum number of 117 females was counted in one winter quarter on a seriously infested tree.

On old trees heavily covered with mosses and lichens, females are chiefly to be found overwintering singly in lichens. Pupation skins and empty exuviae of other insects may be discovered in the overwintering hiding places. The females show a great tendency to retreat into these exuviae. A maximum number of 57 females was counted hiding in exuvia. Normally, however, the number of females overwintering in one place is between 10 and 15.

The position of the winter quarters on the trees shows that although the insects select a moist spot, they do, however, keep away from locations directly exposed to snow and rain. The majority of the winter quarters are located at points which cannot be directly wetted by rain or snow or at least where there is a possibility for the rain or snow to drain off, in other words on vertical or sloping surfaces in the boughs of a tree.

Various other species of spider mites occur together with *T. viennensis* in the webs of the winter quarters. The species most frequently encountered is *Eotetranychus pomi* Sepasgosarian. But *T. viennensis* and *E. pomi* do not mix in one and the same overwintering ball. The insects remain separated according to species under the same bark protection. Furthermore, bark inhabitants from the group of Oribatidae and also predatory mites are to be found in the winter quarters. The predatory mites include the *Typhlodromus* species and *Mediolata mali* Ewing, which reduce the number of harmful spider mites during the course of winter dormancy. It was not directly observed how a *Typhlodromus* species sucked out winter females but in the immediate vicinity of sucked-out winter females, several were found which had reddish coloured intestinal contents. No cases were established, however, of all the spider mites in a winter quarter being killed.

### B. Overwintering

During the course of the winter 1953/54, counts were taken in winter quarters to determine the mortality rate of *T. viennensis*. The insects were removed from their natural surroundings and transferred to the laboratory where they were counted under the binocular lens. The results of the counts are given below in Table 4.

From the figures given in this table, it will be noted that approximately a quarter of the overwintering spider mites die during the course of winter dormancy either due to weather influences or because they are killed in attacks by predators. The mortality quotas recorded on the first three counting dates may be attributed to the feeding activities of the predatory mites whereas the great increase in the mortality figures on February 12 and March 2, 1954, is undoubtedly due to the varying weather conditions in January and February. The weather is the factor which has the greatest influence

*Table 4:* Mortality of *Tetranychus viennensis* during the winter of 1953/54 in apple orchards at Stuttgart-Birkach.

| Count taken on: | Total No. of insects | Living | | Dead | |
|---|---|---|---|---|---|
| | | absolute | % | absolute | % |
| 17. 11. 53 | 352 | 337 | 96 | 15 | 4 |
| 14. 12. 53 | 412 | 385 | 93 | 27 | 7 |
| 5. 1. 54 | 327 | 299 | 91 | 28 | 9 |
| 12. 2. 54 | 414 | 285 | 78 | 82 | 22 |
| 24. 3. 54 | 439 | 346 | 79 | 93 | 21 |
| 13. 4. 54 | 374 | 288 | 77 | 86 | 23 |

upon the natural mortality rate. The feeding activities of predatory mites are of secondary importance in comparison with the weather.

The most favourable winter weather conditions are low temperatures combined with a relative humidity of almost 100 %. A high relative humidity prevails in the winter quarters of *T. viennensis* because the dead parts of the bark store water which they give off gradually in dry periods. In extreme cases, winter females may freeze for short periods without suffering any serious harm in consequence.

### C. Migration of females of *Tetranychus viennensis* from their winter hiding places

In spring as the temperature rises, the females begin to thaw out of their state of winter rigidity. They become active, crawl around in their hiding places, and creep out into the open when the temperature increases again, and move about on the surface of the bark. On warm days in early Spring, females of *T. viennensis* may be seen moving around in a most lively manner on parts of the tree top exposed to the sunshine long before the actual start of the vegetation period. As soon as the sun disappears, the insects creep back again under protected parts on the boughs and branches. Warmth is the chief factor which entices the winter females out of their hiding places and to search for food.

In 1953, the first females in search of food were observed on March 22 on the bark of apple trees growing on the east slope of the Ramsbach valley near Stuttgart-Birkach. On this date, the mean daily temperature was almost 10 ° C. A period of temperatures ranging from 3·6 to 8·6 ° C followed from April 5 to 17, 1953, during which time the females remained concealed in their hiding places. It was not until April 18 that the temperature rose again to 10·4 ° C, and then the females reappeared to take up once more their search for food.

In 1954, the winter females emerged from their winter quarters around April 1, disappeared again, and did not come out again until the end of the month (April 27). On April 3 and 4, there was a mean daily temperature of 10·8 and 12 ° C, respectively. The temperature then dropped again to a level of 1·2 to 7·7 ° C from April 5 to 22. It was not until April 23 onwards that the temperatures began to rise again so that the mites were enticed out of their hiding places.

According to the observations reported above, the daily temperatures must be between 9 and 10 ° C on the average in order to induce the spider mites to leave their winter quarters. These temperatures also cause an accelerated development of the fruit trees so that by the time the bulk of the spider mites have migrated, it can be expected that there will also be an abundance of food available.

In their search for food, the mites migrate from the main boughs over secondary boughs to branches and fruit wood where they firmly settle on buds and young leaves and immediately start their sucking activities. During the three years of studies conducted on the hawthorn spider mite, it was observed that in all cases only one, or at the most two females settle on a leaf in order to build up a population. The winter females are chiefly to be found in the upper parts of the crown on old trees, and also in the lower parts of the crown on young trees.

The winter females differ from the summer females. They are flatter in their structure, have a bright ruby-red colour, and mostly light yellow to sandy-coloured legs. The ruby-red colour conforms with the red colour of the bark on many stone fruit trees so that it is sometimes very difficult to find winter females on stone fruit when they are concealed in hiding places under the bark.

## D. Development and life-cycle of the mites

### 1. Method of studies

Following several unsuccessful preliminary tests, the method described by Andersen (1947) for *Metatetranychus ulmi* was modified. Instead of cut branches, young apple seedlings were used. The plants were set out in 1953 and 1954 in the field in an earth-house covered with garden frames to eliminate any influence upon the tests by rainfall. The sides of the earth-house were open so that there would not be any considerable differences between the temperature and the relative humidity prevailing in the earth-house and the open. The glass panes were shaded whenever the sun was shining strongly. The temperatures and the relative humidity were checked by means of a thermohygrograph.

In order to keep a check on the insects on the leaves, each test plant was examined every day at the same time, and changes in the biological process were noted in a daily schedule. In addition to individual observations, a group observation was carried out for groups of no more than 15 insects.

### 2. Sequence of generations

The studies conducted outdoors during 1953 and 1954 (Figs. 21 and 22) provided information on the number and temporal occurrence of generations of *T. viennensis*. The studies started with the winter females. The interval elapsing from the first egg laid until the last imago emerged within a generation, was taken as the length of a generation.

It is very difficult to make an exact distinction between the different generations for various reasons. The females do not all leave their winter quarters at the same time. Consequently, the commencement of oviposition is delayed in certain cases. Furthermore, the females differ in their reaction

to temperature and relative humidity. They do not live to a constant age so that variations among the different generations ensue.

*1953 Outdoors*

The first outdoor generation began on April 23, 1953 (Fig. 21, Table 6), and lasted until July 25, 1953. Favourable temperatures (Table 5) prevailed at the commencement of the first generation so that the females were induced to leave their winter quarters early. They very quickly completed their feeding activities to attain maturity, and started to lay eggs. During the second ten-day period in April, the temperature rose to a level of 8·6 °C on the average and the relative humidity was 75 %, while in the last ten days of April, a temperature of 11·5 °C and a relative humidity of 59 % were recorded. Around the 10th of May, the temperatures dropped suddenly to 3·4 °C, but rose again during the second 10 days of May (mean of 15·1 °C), and reached an average level of 15·5 °C in the last ten days of May.

*Table 5:* Temperature (in °C) and relative humidity (in %) prevailing outdoors in 1953 (mean per ten-day period).

| | May | | June | | July | | August | | September | | October | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °C | % | °C | % | °C | % | °C | % | °C | % | °C | % |
| 1st ten days | 10·6 | 65 | 13·1 | 75 | 17·8 | 82 | 15·2 | 72 | 15·6 | 65 | 8·8 | 82 |
| 2nd ten days | 15·1 | 63 | 14·9 | 82 | 16·0 | 75 | 19·3 | 69 | 12·9 | 77 | 12·0 | 86 |
| 3rd ten days | 15·5 | 75 | 17·0 | 86 | 18·0 | 75 | 15·1 | 73 | 12·7 | 84 | 9·2 | 89 |

The weather prevailing (Table 5) at the beginning of the first generation meant that the following populations were able to increase greatly in numbers. The second generation began on May 27 and ended on August 18. In comparison with the first generation which had a life of 93 days, the second generation only lasted 84 days. The third generation which began on July 6 and came to an end on October 20, continued to exist for 106 days. The fourth generation began on August 1, and lasted almost as long as the third generation, namely 105 days. The fifth generation made its appearance on August 11, and came to an end together with the fourth generation on November 13, 1953; it lasted 94 days.

*Table 6:* Commencement and end of the different generations of *Tetranychus viennensis* outdoors in 1953.

| | 1st generation | 2nd generation | 3rd generation | 4th generation | 5th generation |
|---|---|---|---|---|---|
| Commencement | 23. 4. | 27. 5. | 6. 7. | 1. 8. | 11. 8. |
| End | 25. 7. | 18. 8. | 20. 10. | 13. 11. | 13. 11. |
| Length (in days) | 93 | 84 | 106 | 105 | 94 |

Summer temperatures prevailed during the second generation until the start of the fifth generation. On the average, these temperatures ranged between 13·1 °C during the first ten days of June and 19·3 °C during the second ten days of August. The temperatures resulted in a continuous development

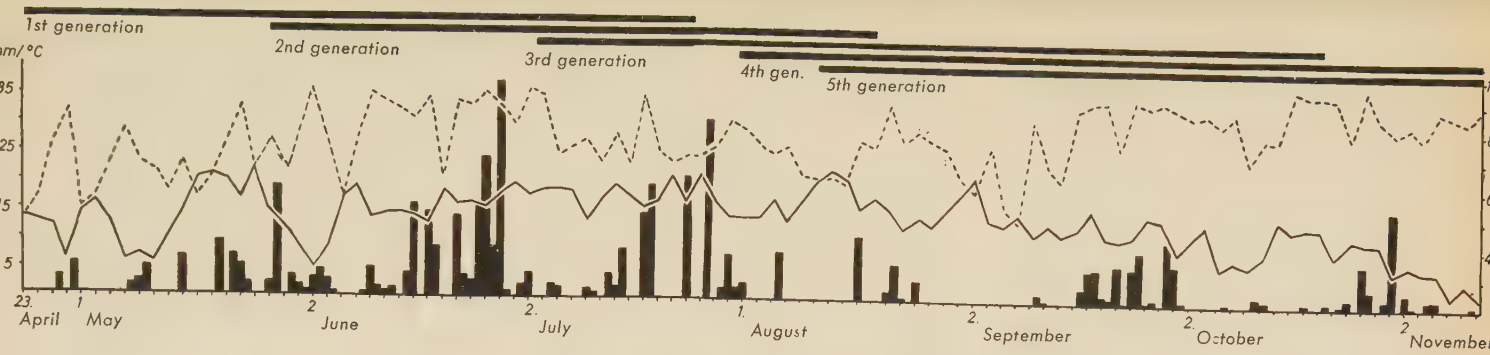


Fig. 21: Sequence of generations and weather conditions outdoors in 1953
--------- = rel. humidity (%); ——— = temp. (°C); ▮ = rainfall (mm)

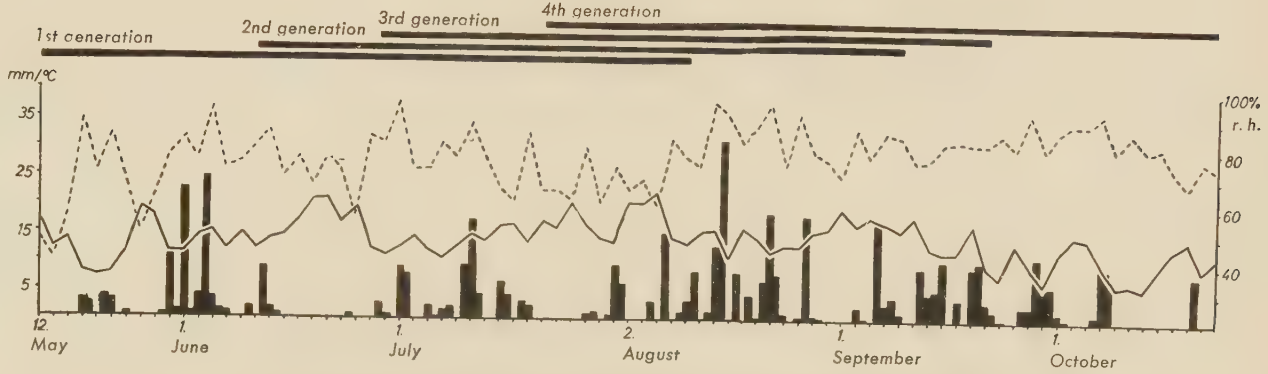


Fig. 22: Sequence of generations and weather conditions outdoors in 1954 (key as for Fig. 21)

of the spider mites, which did not slow down until the end of August to beginning of September. From the end of May (the beginning of the second generation), the generations overlap (Fig. 21, Table 6) so that several (up to three) occur together. Towards the end of the vegetation period, four generations are to be found together for a brief spell. A partial sixth generation — its biological data have, however, not been taken into consideration — appears in the last ten days of August.

Altogether, five generations occurred in sequence outdoors during the course of the vegetation period in 1953 (Fig. 21, Table 6).

*1954 Outdoors*

The mean temperatures during the first and second ten days in April, 1954 were 5·9 and 4·3 °C, respectively. The low temperatures prevented a timely migration of the winter females from their winter quarters so that the leaves already present on the trees were not colonized until the last ten days of April when the mean temperature had reached a level of 8·6 °C. Correspondingly, the first generation did not begin until three weeks later than in 1953 (Fig. 22).

*Table 7:* Temperature (in °C) and relative humidity (in %) prevailing outdoors in 1954 (mean per ten-day period).

| | May | | June | | July | | August | | September | | October | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | °C | % | °C | % | °C | % | °C | % | °C | % | °C | % |
| 1st ten days | 10·1 | 69 | 13·9 | 78 | 12·6 | 80 | 18·2 | 71 | 17·7 | 78 | 9·2 | 85 |
| 2nd ten days | 12·3 | 61 | 16·4 | 75 | 15·0 | 75 | 14·4 | 82 | 13·7 | 84 | 9·9 | 80 |
| 3rd ten days | 12·7 | 73 | 16·4 | 73 | 16·5 | 69 | 14·2 | 82 | 9·3 | 82 | 10·2 | 83 |

The weather prevailing (Fig. 22, Table 7) during the four generations that occurred in 1954, was less favourable for the development of spider mites than the weather in 1953. Particularly the May temperatures necessary for a rapid development of the first generation in Spring, were below the values recorded for the same periods in 1953. The following mean temperatures were registered: 1st ten days of May, 1953: 10·6 °C; same period in 1954: 10·1 °C; 2nd ten days of May, 1953: 15·1 °C; same period in 1954: 12·3 °C.

The temperatures prevailing during the first and second ten-day periods in June, 1954 were also lower than those recorded during the same periods in the previous year. It is, therefore, comprehensible that the first and second generations did not develop rapidly so that during the further course of the

*Table 8:* Commencement and end of the different generations of *Tetranychus viennensis* outdoors in 1954.

| | 1st generation | 2nd generation | 3rd generation | 4th generation |
|---|---|---|---|---|
| Commencement | 10. 5. | 11. 6. | 28. 6. | 21. 7. |
| End | 19. 8. | 9. 9. | 21. 9. | 22. 10. |
| Length (in days) | 101 | 90 | 85 | 93 |

year the spider mites were not able to make up for this hindrance to their development brought about by the unfavourable temperatures which prevailed in Spring. Accordingly, there were only four generations (Fig. 22, Table 8), being fewer than in 1953.

It is also noticeable that towards the end of the vegetation period, the 1954 generations came to an end earlier than in 1953. This is also due to the temperatures because the corresponding values recorded in 1953 were slightly higher than in 1954.

A comparison of the lengths of the individual generations (Tables 6 and 8) drawn between 1953 and 1954, shows that in 1954 at low temperatures, the first two generations lasted longer. This is to be attributed to the considerably lower mean temperature prevailing at times in the early stage of the vegetation period with the result that the development of the mites proceeded at a slow rate and the generations consequently continued to exist for a longer period. All the 1954 generations overlap because, compared with 1953, the first commenced later and the last one ended earlier.

### 3. Development of the different stages

In order not to widen the scope of this paper too much, summaries will merely be given of the investigations conducted in this section. Individual reports on the observations made, data on the biological studies and the calculation of the biological data are available at the Institute for Plant Protection. Agricultural College, Stuttgart-Hohenheim.

After they have been laid, the eggs of the hawthorn spider mite are at first bright and have a glassy shimmer. During the process of embryonic development, they change colour depending upon the season. In Spring (about the end of May), a change of colour is hardly noticeable when the sequence of development proceeds rapidly. The change in colour is first apparent when there is a lack of food for the mites. In this event, the eggs may have a whitish to light yellow colour immediately after they have been laid, and quite often this colour will change first to sandy-yellow and then to egg yellow during the course of embryonic development. Shortly before the larva hatches out, the eggs appear whitish and non-transparent although the reddish eyes are clearly perceptible.

The colour of the freshly emerged larva is whitish to light yellow although it changes immediately the larva has consumed food, to a light greenish-yellow. Dark green to greenish-black intercalations are visible through the integument, just as in both nymphal and all quiescent stages.

After emerging from the first quiescent stage, the protonymph still has its larval colour. This changes as more food is taken. The previous colour of light greenish-yellow turns to dark yellowish-green or deep green. The female deutonymph has the same colour as the protonymphal stage shortly before it enters the second quiescent stage. In fact, it retains this colour. The male deutonymph differs from the female in colour. At the beginning of the second nymphal stage, the male still has the same colour as the protonymph. Later, it fades, and becomes light yellow shortly before the third quiescent stage.

The values given below for the feeding and quiescent periods of the different stages represent the mean calculated from the data obtained for all generations of one year (Tables 9, 10). The number of insects examined

refers to the total number of insects of all generations occurring in one vegetation period.

*1953 Outdoors*

In 1953, a total of 521 females and 224 males were observed right through from the egg to the imago in all five field generations. The insects of the first generations developed at the fastest rate because favourable temperatures prevailed in Spring (cf. "Sequence of generations outdoors in 1953"). The entire development of the males took 15·9 days while the development of the females was completed in 16·7 days.

The males reached the adult stage in a shorter time than the females. This applied to all field generations in 1953 and 1954.

*Table 9:* Total development of *Tetranychus viennensis* outdoors in 1953 (expressed in days).

| | 1st generation | 2nd generation | 3rd generation | 4th generation | 5th generation | Average |
|---|---|---|---|---|---|---|
| Females | | | | | | |
| Embryonic period | 5·7 | 9·0 | 7·9 | 8·1 | 15·0 | 9·4 |
| Larva | 1·5 | 1·7 | 1·6 | 1·9 | 2·2 | 1·8 |
| 1st quiescent stage | 1·4 | 1·4 | 1·4 | 1·8 | 2·4 | 1·7 |
| Protonymph | 2·5 | 2·5 | 2·4 | 2·6 | 3·6 | 2·8 |
| 2nd quiescent stage | 1·4 | 1·3 | 1·5 | 1·8 | 2·6 | 1·8 |
| Deutonymph | 2·3 | 2·5 | 2·6 | 2·9 | 3·9 | 3·0 |
| 3rd quiescent stage | 1·9 | 1·9 | 2·0 | 2·9 | 3·9 | 2·8 |
| Total development | 16·7 | 20·3 | 19·4 | 22·0 | 33·6 | 23·3 |
| Males | | | | | | |
| Embryonic period | 6·0 | 8·4 | 8·1 | 8·3 | 15·4 | 9·0 |
| Larva | 1·7 | 1·5 | 1·4 | 1·7 | 2·2 | 1·7 |
| 1st quiescent stage | 1·4 | 1·4 | 1·4 | 1·9 | 2·3 | 1·7 |
| Protonymph | 2·2 | 2·4 | 2·4 | 2·6 | 3·6 | 2·6 |
| 2nd quiescent stage | 1·0 | 1·4 | 1·3 | 1·9 | 2·5 | 1·6 |
| Deutonymph | 2·0 | 2·2 | 2·3 | 2·7 | 3·5 | 2·5 |
| 3rd quiescent stage | 1·6 | 1·4 | 1·5 | 1·9 | 2·7 | 1·8 |
| Total development | 15·9 | 18·7 | 18·4 | 21·0 | 32·2 | 20·9 |

The individual values fluctuate very slightly (Table 9). The embryonal development of the females took 5·7 days, and that of the males 6 days. The interval from the emergence of the larva to the protonymph was 2·9 days for the females, and 3·1 days for the males whereas the time which elapsed between the protonymph and the deutonymph was calculated at 3·9 days for the female, and 3·2 for the male. In the last two stages — deutonymph and third quiescent stage — the females take 4·2 days to develop, and the males 3·6 days. It is during these two stages that the greatest differences are esta-

blished between females and males for all field generations occurring in 1953 (Fig. 23). The males take less time than the females to pass through the deutonymphal and the third quiescent stages (Table 9).

As the vegetation period continues, the development times become longer from the second to the fifth generation. This increase is slight during the second to the fourth generation, but in the fifth generation it is considerable. Summer temperatures prevail during the second to the fourth generation but the fifth generation continues well into the Autumn so that the lower temperatures prevailing at this time of the year cause the spider mite development to be slowed down and delayed. Females and males in the fifth field generation take twice as long as the first generation to develop from the egg to the imaginal stage. The most obvious delay in development is during the

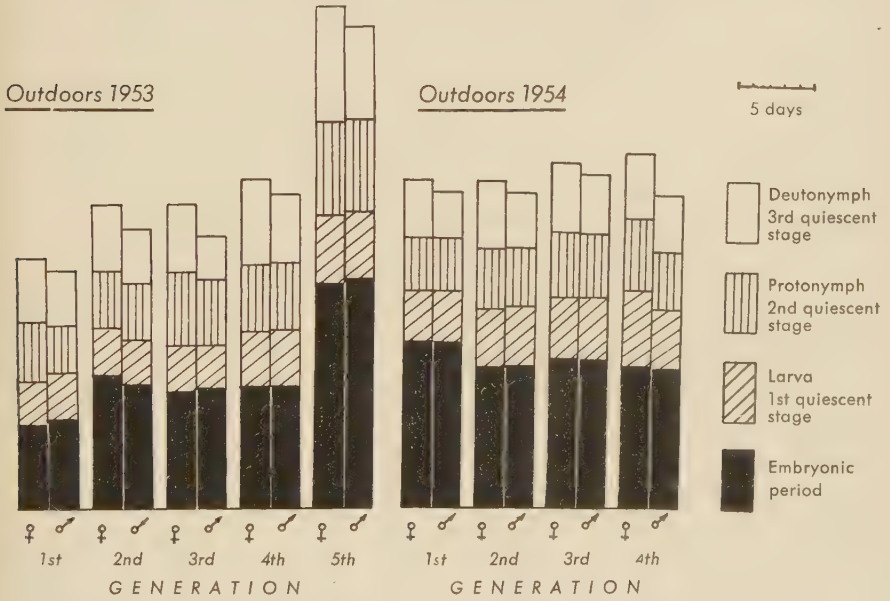


Fig. 23: Development of the different stages outdoors in 1953 and 1954

embryonic stage which, in the fifth generation, lasts approximately 2½ to 3 times longer than in the first generation. (Females: 1st generation — 5·7 days; 5th generation — 15 days. Males: 1st generation — 6 days; 5th generation — 15·4 days). The longer development times in the different stages are most obvious although not so pronounced as in the embryonic development.

*1954 Outdoors*

The four field generations of 1954 developed in a more uniform manner than the 1953 generations (Fig. 23, Table 10), since concordant values were obtained. A total of 4,096 females and 890 males were observed and studied.

As in the preceding year, it was established in 1954 that the development period increased slightly during the course of the vegetation season (Table 10). The females took longer to reach the adult stage than the males, just as they did outdoors in 1953.

The weather conditions in 1953 were favorable for the development of the spider mites but unfavourable in 1954 (cf. "Sequence of generations"). As a result, the time spent in the embryonic stage was also longer in the first generation in 1954; in this year the time taken for the embryonic stage to be completed was about twice as long as that taken by the first generation to pass through the same stage in 1953 (Fig. 23, Table 10).

*Table 10:* Total development of *Tetranychus viennensis* outdoors in 1954 (expressed in days).

| | 1st generation | 2nd generation | 3rd generation | 4th generation | Average |
|---|---|---|---|---|---|
| Females | | | | | |
| Embryonic period | 11·1 | 9·6 | 10·1 | 9·6 | 10·1 |
| Larva | 1·8 | 1·9 | 2·0 | 2·5 | 2·0 |
| 1st quiescent stage | 1·7 | 1·9 | 2·1 | 2·5 | 2·0 |
| Protonymph | 2·0 | 2·2 | 2·3 | 2·7 | 2·3 |
| 2nd quiescent stage | 1·5 | 1·8 | 2·0 | 2·1 | 1·8 |
| Deutonymph | 1·9 | 2·2 | 2·3 | 2·4 | 2·2 |
| 3rd quiescent stage | 2·0 | 2·3 | 2·4 | 2·0 | 2·2 |
| Total development | 22·0 | 21·9 | 23·2 | 23·8 | 22·6 |
| Males | | | | | |
| Embryonic period | 11·1 | 9·7 | 10·0 | 9·4 | 10·1 |
| Larva | 1·8 | 1·9 | 2·1 | 2·0 | 1·9 |
| 1st quiescent stage | 1·7 | 1·9 | 2·1 | 2·0 | 1·9 |
| Protonymph | 1·9 | 2·2 | 2·3 | 2·1 | 2·1 |
| 2nd quiescent stage | 1·6 | 1·8 | 1·9 | 1·7 | 1·7 |
| Deutonymph | 1·8 | 2·1 | 2·2 | 1·9 | 2·0 |
| 3rd quiescent stage | 1·3 | 1·6 | 1·8 | 2·0 | 1·7 |
| Total development | 21·2 | 21·2 | 22·4 | 21·1 | 21·4 |

### 4. Life-cycle of imagines

The age of the imagines is calculated from the time the insect emerges out of the third quiescent stage until it dies. To determine this factor, the values for 1953 and 1954, just as in the tests described above, were recorded separately according to the sex. For the females, only those insects were included in this study, which were definitely known to have died naturally. For the males, the first insect of a population was taken in each case to establish the age.

Whereas the females outdoors in 1953 lived to an average age of 20·5 to 30·3 days (80 insects), the average age of the 1954 females was 24·1 to 40·5

days (110 insects). The age of the mites varies from generation to generation and the absolute figures within a generation differ most considerably. A female of the first field generation in 1954 lived for the longest period, namely from May 10 to August 1 making a total of 83 days.

The life-period of the mites is dependent not only upon the feeding conditions but also upon the temperature. A high temperature causes a greater rate of metabolism, with the result that the mites age more rapidly.

The life-period of the males is very much more difficult to determine than that of the females because the males of *T. viennensis* move about in a lively manner on the leaves and often fall off so that they are lost. In the field, the males of the 1953 population attained an average age of 8·4 to 11·3 days (763 insects) while the 1954 males lived on the average for 8·9 to 15·9 days (1474 mites).

When the development periods from the emergence of the larva until the death of the fully grown mite are taken into consideration, it is found that the females of the 1953 population occurring outdoors have an overall life-period averaging 41·5 days, those of the 1954 population 39·5 days, while the 1953 males live for 21·7 days and the 1954 males for 24·9 days.

### 5. Oviposition of winter and summer females

*a) Location of oviposition*

Under normal conditions, a hawthorn spider mite population develops on the underside of the leaves. This is most favourable particularly for the juvenile stages because they are thus afforded a greater degree of protection. It is only when the mites have sucked at the underside to a considerable extent that they migrate to the upper surface.

The females cover the underside of the leaves with a dense web of threads which they secure to veins and hairs. A thick web was never found on the upper leaf surface. The threads are as clear as glass, and are never spun directly on the surface of the leaf. A definite arrangement of the threads is not perceptible. They are spread out at random in all directions from one point to another where they are secured. There is adequate room inside the web itself for the mites to move around freely.

The majority of the eggs are laid on the underside of the leaves, particularly in the hiding places on the main and secondary veins, and also hanging loosely in the web. An isolated female distributes its eggs on a leaf in a definite manner (Fig. 24). The eggs are concentrated on that part of the leaf which a female has covered with a web while feeding to reach maturity. A spider mite population that develops in this web is afforded excellent protection against falling.

*b) Number of eggs laid by winter and summer females; period of oviposition*

The winter and summer females lay the same number of eggs. The number of eggs laid daily, however, depends largely upon the weather, in particular upon the temperature and the amount of food available. The number of eggs laid by the winter females is greatly influenced by the temperature although in this case the food factor is not so important because the winter females always migrate to fresh leaves.

In 1953, the first winter females emerged from their winter hiding places during the last ten days of March. About 30 days elapsed before the first

Fig. 24: Distribution of eggs on the underside of the leaf by a single female

egg was laid (April 26). In the interim period, the females carried on their maturity feeding activities which were interrupted by two cold spells around April 7 and between April 13 and 17.

The winter females laid an average of 1·7 eggs daily outdoors in 1953 (Table 11). In the heavy period of egg-laying which set in at the commencement of the first generation, 5 to 7 eggs per mite were counted each day. This high number of eggs resulted in a rapid increase of the spider mite population.

The temporal extension of maturity feeding by the winter females has no influence upon the extent of total oviposition. The ovipositional period of the winter females lasted on the average 21 days outdoors in 1953 (Table 11). The maximum number of eggs laid by one female was 103, the average number being 36. In the second and third generations (summer females), the average number of eggs laid decreased, only to rise again in the fourth and fifth generations.

The females of the second generation laid on the average 33·4 eggs (maximum of 111) over an ovipositional period averaging 24·6 days (maximum 45 days). The maximum number of eggs laid by a female in one day was 7, the average being 1·4. The majority of the isolated females of the second generation laid an average of 1 or 2 eggs daily.

In the third generation, the average ovipositional period was 15·2 days, and 29·6 eggs (maximum of 102) were counted per mite. The largest number

*Table 11:* Ovipositional periods and number of eggs laid by *Tetranychus viennensis* per mite for the field generations in 1953 and 1954 (average for the different generations).

| | Ovipositional period (days) | Total no. of eggs laid per mite | | No. of eggs laid daily per mite | |
|---|---|---|---|---|---|
| | | Average | Maximum | Average | Maximum |
| 1953 | | | | | |
| 1st generation | 21·0 | 36·0 | 103 | 1·7 | 7 |
| 2nd generation | 24·6 | 33·4 | 111 | 1·4 | 7 |
| 3rd generation | 15·9 | 29·6 | 102 | 1·9 | 5 |
| 4th generation | 20·8 | 38·7 | 96 | 1·9 | 5 |
| 5th generation | 21·9 | 37·5 | 100 | 1·9 | 3 |
| 1954 | | | | | |
| 1st generation | 38·6 | 85·2 | 154 | 2·2 | 9 |
| 2nd generation | 24·1 | 56·2 | 111 | 2·3 | 6 |
| 3rd generation | 22·3 | 49·2 | 58 | 2·2 | 5 |
| 4th generation | 22·3 | 39·2 | 87 | 1·8 | 5 |

of eggs laid in one day by a female of the third generation was five. The average number laid daily was, however, only 1 or 2 in most cases.

In the fourth generation, the average egg production and the mean ovipositional period for one female increased again although the number of eggs laid daily remained the same as that recorded for the third generation. The females of the fourth generation each laid 38·7 eggs (maximum of 96) over an ovipositional period of 20·8 days on the average. The average number of eggs laid daily was 1·7 per mite.

The number of eggs laid, the daily egg production and the ovipositional period recorded for the fifth generation differ very little from the values obtained for the fourth generation. The ovipositional period of the females increased slightly to 21·9 days but the total number of eggs laid per mite decreased to 37·5 (maximum of 100) so that each female laid on the average 1·7 eggs daily.

The position was somewhat different outdoors in 1954. The average number of eggs laid daily by each winter female was 2·2 as compared with 1·7 in the preceding year. Yet at the beginning of the first generation, the same number of eggs was laid daily (5 to 7) because temperatures ranging from 12 to 16·7 ° C prevailed between May 9 and 17. A cold period set in on May 18 so that the average number of eggs laid daily by each female dropped to 1 or 2. In the first generation, the winter females therefore built up a very large population which is reflected in the length of the ovipositional periods, the average total numbers of eggs laid, and the average daily egg production.

Most varying values are obtained for the number of eggs laid daily by the first field generation in 1953 and 1954. The reason for this is probably the longer life-periods of the winter females of 1954, which enjoyed better climatic conditions as the temperatures continued to increase enabling them to give a bigger egg production.

During the second 1954 generation, there was relatively heavy rainfall accompanied by low temperatures and high relative humidity resulting in an inhibition of the spider mite development. Consequently there was a considerable drop in the values obtained for the ovipositional periods and the number of eggs laid per female.

The mean ovipositional periods registered for the 1953 and 1954 females are very similar. In 1953, the females laid eggs on 21·5 days, and 1954 on 25·7 days. The average number of eggs laid by each female varies, however, being 34·8 per insect in 1953 and 54·2 eggs per female in 1954. Although the weather conditions in 1953, particularly in Autumn, were more favourable than in 1954, the average number of eggs laid daily by each female was higher in 1954. In 1953, the average was 1·6, and 2·1 in 1954. According to the observations made in these investigations, the reason for this difference may be attributed to the fact that the 1953 generations developed at a slower rate than those occurring in 1954, and also that the third, fourth and fifth 1953 generations, in particular, continued to exist well into the Autumn whereby decreasing temperatures caused a drop in the intensity of the biological process. In 1954, on the other hand, the generations were formed more rapidly, and despite the wet Summer, they were able to develop over a long period in favourable temperature conditions.

### 6. Pre-ovipositional and post-ovipositional periods

After emerging from the third quiescent stage, the female imagines begin their maturity feeding activities. They increase in size considerably. The length of this feeding period, known as the pre-ovipositional period, during

*Table 12:* Pre-ovipositional and post-ovipositional periods of winter and summer females of *Tetranychus viennensis* (expressed in days).

| | 1st generation | 2nd generation | 3rd generation | 4th generation | 5th generation | Average |
|---|---|---|---|---|---|---|
| Outdoors 1953 | | | | | | |
| Pre-ovipositional period | 5·6 | 4·2 | 3·5 | 2·9 | 3·3 | 3·0 |
| Post-ovipositional period | 3·5 | 1·6 | 0·9 | 1·4 | 0·8 | 1·6 |
| 1954 | | | | | | |
| Pre-ovipositional period | 1·7 | 2·6 | 3·2 | 1·8 | — | 2·3 |
| Post-ovipositional period | 0·5 | 0·7 | 0·6 | 1·4 | — | 0·8 |

which the ovaries or eggs mature, is dependent upon the temperature and the food available.

The pre-ovipositional period of winter females living outdoors varied between 5·4 and 5·9 days. In 1954, the corresponding values obtained were 1·4 to 2·9 days (Table 12). On the average, the maturity feeding period of the summer females outdoors lasted between 2·9 and 5·9 days for all generations in 1953. The corresponding pre-ovipositional period recorded for 1954 was between 1·7 and 3·2 days (Table 12).

On completion of oviposition, the females pass through a more or less long post-ovipositional period which was calculated at 0·8 to 3·5 days as an average for all generations occurring outdoors in 1953. The corresponding values calculated for 1954 were between 0·5 and 1·4 days (Table 12).

### 7. Numerical ratio of males to females, parthenogenesis, and number of eggs laid by unfertilized females; mating

A large number of individual observations have been made in the field, and therefore it is possible to gain an impression of the numerical ratio of males to females for *T. viennensis* in 1953 and 1954. Andersen (1947) and also Newcomer and Yothers (1927) presume that for *Metatetranychus ulmi*, a male to female ratio of 1:1 is correct. The studies conducted in this work show that with respect to *T. viennensis*, the females are in the majority, and furthermore that one male fertilizes several females.

The averages calculated for all generations occurring in the field show that for 1953 the numerical ratio of males to females was 1:2·2, whereas in 1954 it was 1:4·3 (Table 13).

It was to have been expected that the ratio of males to females would change in favour of the males in the last generations of the year so that all the females could enter into the overwintering stage fertilized. However, this theory was not confirmed. It is noticeable that towards the end of the vegetation period, there is an increase in the number of females to each male. This was particularly the case in 1954. This tendency is not perceptible for 1953 evidently due to a lack of numerical data. On the other hand, there appear to be fewer females to each male when a population first starts to form in Spring.

The females can lay eggs without previously being fertilized, although only males develop from these eggs. However, as there are always sufficient

*Table 13:* Numerical ratio of males to females for *Tetranychus viennensis* in 1953 and 1954.

| | Outdoors / 1953 | Outdoors / 1954 |
|---|---|---|
| | ♂♂ : ♀♀ | ♂♂ : ♀♀ |
| 1st generation | 21 : 64 = 1 : 3·0 | 267 : 969 = 1 : 3·6 |
| 2nd generation | 61 : 69 = 1 : 1·1 | 294 : 1223 = 1 : 4·2 |
| 3rd generation | 36 : 69 = 1 : 1·9 | 186 : 891 = 1 : 4·8 |
| 4th generation | 78 : 207 = 1 : 2·7 | 138 : 762 = 1 : 5·5 |
| 5th generation | 28 : 12 = 1 : 0·4 | |

males available for the purpose of fertilization, a female which exclusively lays male eggs is very rare, or can only be induced to do so under artificial conditions. No difference was established between the laying rate of fertilized and unfertilized females.

The females are puberal immediately they emerge from the third quiescent stage, and mating can take place at once. The males require a short pause after emerging in order to attain puberty.

In most cases, several males surround a deutonymph in its third quiescent stage.

As soon as the young female imago emerges out of the third quiescent stage, a male moves under it. The male then holds itself tightly to the leaf surface by means of its first, second and fourth pair of legs, and embraces the female by placing its third pair of legs between the bases of the female's third and fourth pairs of legs. The male curves its abdomen upwards and slightly forwards until it reaches the genital orifice of the female with the tip of its abdomen. The entire process of copulation hardly lasts more than two to five minutes.

Generally, there is always an adequate number of males present on one leaf. Consequently the fertilization of the females is ensured. It was frequently observed outdoors in 1954 that female imagines, already several days old but which had not yet proceeded to start egg-laying, could also copulate. The colour of the imagines changes at some time between their emergence from the third quiescent stage and the start of oviposition, namely from a deep greenish-yellow to a typical bluish-violet, shimmering matt carmine-red. Copulations were observed among many insects with the most varied of colour shades during the period when the colour of the insects changes.

From this, it was concluded that a female imago is copulated not only once but several times. Close studies confirmed this assumption, and it was discovered that a female passing through the pre-ovipositional period copulates up to three or four times with different males.

Once they start to lay their eggs, however, fertilized females resist further copulations, and drive away the males in their vicinity.

### 8. Mortality of the different stages of development in 1953 and 1954

The biological observations conducted in 1953 and 1954 were extended also in order to establish the natural mortality rate of all development stages of *T. viennensis*. The mortality percentages of the different stages are based on the initial figure (total number of eggs studied). Table 14 gives the mortality values for all generations of one year.

*1953 Outdoors*

516 mites of both sexes developed from the 739 eggs which were under constant observation in generations 1 to 5. 104 individuals died in the egg stage (14·1 %). The mortality rate among the larvae amounted to 8·1 %, and among the protonymphs and deutonymphs to 3·8 and 0·7 %, respectively. Once they had emerged out of the third quiescent stage, no fully developed mites died during the period of the test. Altogether, a mortality of 197 eggs and juvenile stages was recorded. 26·7 % of the studied eggs and the mites which

developed from them were killed during the course of the vegetation period (Table 14).

*1954 Outdoors*

5753 eggs were studied outdoors during the four generations occurring in 1954. 203 eggs died (4·7 %). The mortality rate among the larvae was 1 % greater than that recorded for the egg stage. Analogous to 1953, the mortality rate of protonymphs sank in 1954 to 3·2 %, and that of deutonymphs to 0·2 %. 797 of the 5753 eggs did not develop as far the imaginal stage. 13·8 % of the originally anticipated imaginal population died during development (Table 14).

The tests revealed that the highest rate of mortality is in the egg stage, followed by the larval, protonymphal and deutonymphal stages for which the values decrease correspondingly. All the deutonymphs which entered the third quiescent stage, emerged as imagines. The observations also show that quiescent stages of the hawthorn spider mite die very seldom. The few dead quiescent stages were therefore added to the active stages. In 1954, only 13 of all the individuals observed outdoors died in the quiescent stage, representing a percentage of 0·0025. The mortality rate among the young imagines — from the time when they emerge out of the third quiescent stage until the start of oviposition — is also extremely slight. It may be concluded from the values obtained that as their development progresses, the mites become more resistant and less dependent upon external influences.

*Table 14:* Mortality rate of the different development stages of *Tetranychus viennensis* outdoors in 1953 and 1954 (expressed as a percentage).

| | Initial figure absolute | Eggs | Larvae | Proto-nymphs | Deuto-nymphs | Imagines | Total mortality |
|---|---|---|---|---|---|---|---|
| 1953 1st—5th generations | 739 | 14·1 | 8·1 | 3·8 | 0·7 | — | 26·7 |
| 1953 1st—4th generations | 5753 | 4·7 | 5·7 | 3·2 | 0·2 | — | 13·8 |

The main causes of mortality in the different generations, are to be attributed particularly to biological factors, and to a lesser degree to the weather. In most cases, the margin of available food is too small. This is reflected particularly in the high mortality rate registered among the juvenile stages (larvae and protonymphs) which only find little food on a densely populated leaf, especially as their sucking organs are still small. Furthermore, the larvae and protonymphs live under the webs spun by old mites, and here the leaf is seriously damaged due to sucking. In contrast, the deutonymphs show a greater tendency to migrate, and search for their food outside the protection of the web.

It is difficult to explain the high rate of mortality in the egg stage. Perhaps it is brought about by internal factors which have an unknown action. The

observations made during the tests indicate that among eggs which develop in periods of low relative humidity, there is a higher rate of mortality than among those which complete their embryonic development at a high relative humidity.

### E. Factors governing the occurrence of winter females

The first winter females occurred outdoors in 1953 about August 22, and in 1954 approximately 10 to 14 days earlier. In 1953, the average temperatures prevailing during the second and the last ten days of August were 19·3 and 15·1 ° C, respectively, and in 1954 14·4 and 14·2, respectively. During the same periods, the relative humidity was 69 and 73 %, respectively, in 1953, and 82 % in 1954. These temperatures permit normal development of the eggs and different stages of *T. viennensis*. Consequently, the temperature and relative humidity cannot be considered as definite factors for the first occurrence of winter females, that is during the above-mentioned periods.

As the season progresses, the damage caused to the leaves of the host plant becomes more and more serious due to the sucking activities of the spider mites. The food margin of a spider mite population becomes narrower. The supply of nutritive substances to the leaves from the plant itself is gradually interrupted. Furthermore, the leaves become harder as they grow older.

This scanty supply of food and the difficulties encountered in the search for nutrition not only slow down the development of the mites but also constitute the main factor for causing the females to change colour. Reiff (1949) investigated the conditions which lead to a change to the winter forms. In respect of *T. urticae*, he established that the proportion of winter form to summer form was 1 : 1 on sap green leaves, 2 : 1 on wilting, yellowish leaves, and 9 : 1 on withered leaves. He discovered winter forms even in Summer on withered leaves. The observations made by Reiff (1949) conform with those made in my own studies.

During the course of normal development by females in Spring and in Summer, the colour of all larval and nymphal stages is greenish. It is not until the females undergo alteration that a change in colour is noticed during the final nymphal stage, and particularly during the third quiescent stage. On the basis of this change in colour, it can be predicted with certainty which deutonymph or which third quiescent stage will develop into a summer or winter female. The colour of deutonymphs or third quiescent stages which develop into winter females, changes from greenish-black to greenish-brown, and then to sandy light brown with intercalations of green. Due to the surface of the integument, however, these colours do not appear uniform but slightly speckled. The female winter imagines also have this characteristic colouring. However, after they have fed for a period, they gain their final, ruby-red pigment intercalation.

As the development period continues (in September, October and also in November under favourable climatic conditions), the food offer becomes even less. The young stages, in particular, suffer as a result of the food shortage. The deutonymphs, however, migrate to a new leaf. At the time of the Autumn populations, the temperatures drop constantly, the days become shorter, and the solar radiation grows weaker. For the spider mites, this means a further reduction of the development intensity. At this time of

the year, it is not only the shortage of food which influences the development of winter females but also the temperature has to be taken into account. At temperatures between 8 and 9 ° C, only winter females occur.

It was established in tests conducted in thermostats, that winter females may occur in Spring on badly nourished leaves. Similar observations were also made in the indoor test. In the thermostats, winter females which emerged in Spring were induced to change into summer females and to lay eggs when offered plenty of nutrition and after passing through a maturity feeding period without a resting pause, but this did not succeed outdoors with winter females of the autumn generations, even when the winter females were placed in a thermostat and on fresh leaves.

The winter females behave in a most special manner until lower temperatures set in, which drive them into a winter quarter. They appear very sluggish. The females are not tied to a definite location but migrate slowly upwards from leaf to leaf in a vertical direction, and finally assemble in large numbers on the leaves at the tip of a branch. When the temperatures drop to a low level, the females retreat to their winter quarters before the leaves fall from the branches. In fact they move away from the leaves as soon as these start to turn yellow.

Andersen (1947) reports that it is not the autumn frosts but the leaves destroyed by the cold, which are the direct cause for the disappearance of spider mites in Autumn. This also applies to *T. viennensis*. The entire autumn population is considerably resistant to drops in temperature and persistent low temperatures. The insects remain motionless on the leaves during such periods, but on warmer days they immediately become active again and recommence their sucking activities. Imagines have rarely been observed on leaves which have turned yellow.

## IV. Epidemiology and Ecology

### A. Weather and change in population density

Analogous to the gradation of other *Tetranychus* species, a large first or second generation is of great importance for building up an annual population also for the hawthorn spider mite. This is also evident from the effective production of the winter females. The oviposition of winter females is extremely intensive from the very beginning. The weather conditions prevailing in Spring cannot be termed as the most favourable for the development of the first generation yet a gradually developing spring population, strong in numbers, is also quite sufficient to cause a mass calamity in Summer. Accordingly, favourable weather conditions in Spring guarantee a big summer population which in turn produces a large number of winter females. On the other hand, poor weather conditions in Spring cause a noticeable reduction of the incidence rate so that even favourable weather in Summer will no longer lead to the development of a harmful population.

In 1953, a young tree heavily colonized by winter females of the hawthorn spider mite was kept under observation in the vicinity of Stuttgart-Hohenheim to check the population growth of this species. From May 10 to June 2, the temperature rose continuously from 5 ° C to more than 25 ° C, and then dropped rapidly so that it fluctuated between 12 and 20 ° C up to the

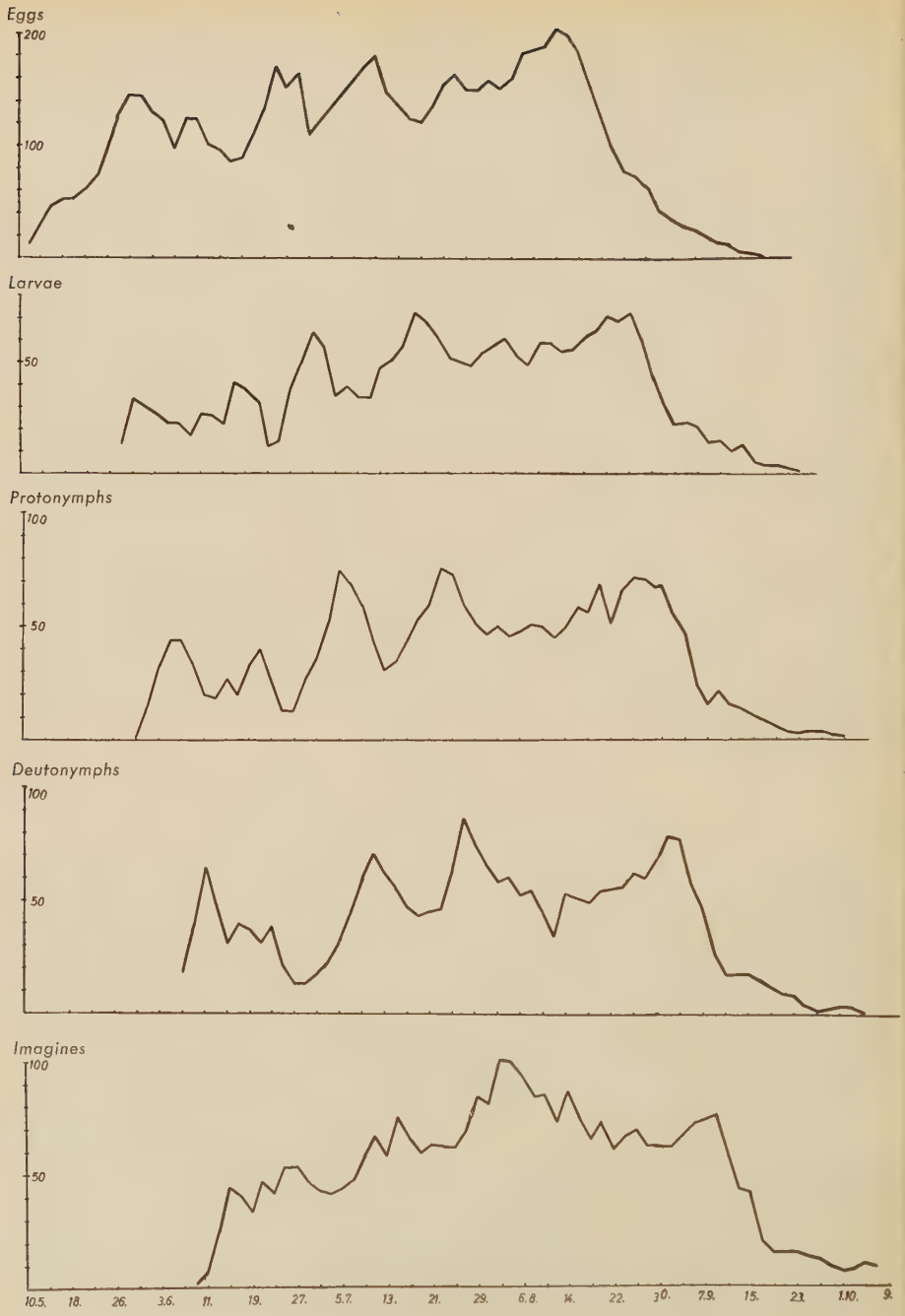


Fig. 25: Population development of *Tetranychus viennensis* outdoors in 1954

end of July. During this period (middle of May to end of July), there was a great amount of rainfall so that the relative humidity was quite high. The first generation developed very quickly, and the second and third generations followed at short intervals with the result that three generations already existed at the beginning of June. Due to the large drop in temperature during the first ten days of June, the development of the mites continued very slowly and as the season progressed the spider mite population became no larger. The population of winter females was 256 strong in Autumn, 1953, counted in 10 winter quarters. In the Winter of 1952/53, 135 females were counted, also in 10 winter quarters.

The same tree was again placed under observation in 1954. During the second ten days of May, the temperatures dropped to 6—7 °C, and then rose again to between 12 and 18 °C in the first half of June, and fluctuated between 11 and 19 °C in July. It was only during the last ten days of May that the spring generation was able to develop rapidly for a few days in favourable weather conditions but then further development was inhibited due to a period of bad weather at the beginning of June. Moreover, the large amount of rainfall and the low temperatures in Summer did not provide an opportunity for a population to be built up equal to that of the preceding year so that in the winter of 1954/55 only 65 winter females were counted in a total of 30 winter quarters.

The results of the counts taken in 1954 are plotted in Fig. 25. Groups of 10 leaves were evaluated at intervals of two days, and the quiescent stages were included in the corresponding active stages. During the course of the year, four generations appeared in all the groups checked. Displacements among the generations occur, however, as the season progresses, and consequently there is overlapping which is particularly evident from the curves plotted for the imagines. All the curves rise as the season continues, and then drop down to zero at the end of the vegetation period. The curve plotted for the imagines is the only one not to drop down to the zero value, due to the fact that the winter females remain on the leaves for a time before they retreat into their winter quarters. The individual generations are clearly perceptible as peaks in all the curves. The peaks of the curve for the first generation, for example, are to be found in temporal succession corresponding to the biological progress of development in the different stages.

The number of winter females present on a tree depends largely upon the ecological conditions, and in particular upon the climatic factors. Favourable temperatures mean that there will be a large number of winter females and consequently continued mass reproduction in the following vegetation period provided that favourable temperatures also prevail later.

### B. Injury

The injuries inflicted by the hawthorn spider mite are typical in the initial stage on all fruit trees attacked by this spider mite species. As a young leaf is in most cases only colonized by a single female, the damage is thus caused by this female and its progeny. A yellowish spot, about the size of a pfennig or a hazel nut, forms on the leaf surface. On the underside of the leaf, this spot is covered by a web. The spot is caused as a result of the sucking activities of the mother insect. As soon as a population begins to

grow, the immediate vicinity of this spot will also be attacked, and during the course of the season the injury extends over the entire leaf so that it perishes.

In cases of serious infestation, the initial injuries are rapidly erased, and the foliage of a tree sucked by spider mites turns to a greyish-yellow colour within a short space of time. Occasionally, brown necrotic spots also appear on the leaves. The damage caused to the plant due to the sucking activities of the mites on the leaves, takes the form of water losses and the removal of assimilates. Mostly the entire content of plasma is removed from the cells and consequently they cease to function. Large quantities of water evaporate through the punctures made by the mites, and these quantities are greater

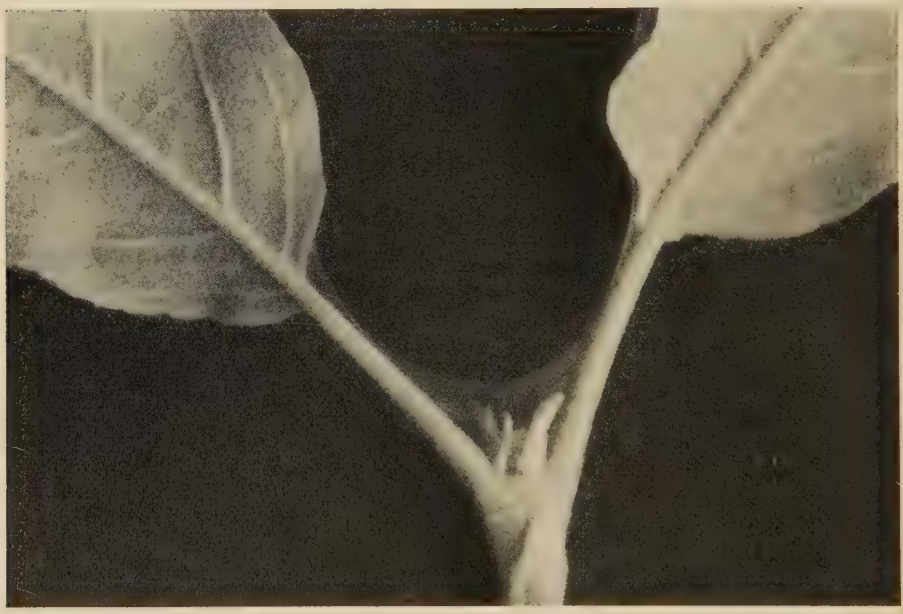

Fig. 26: Web on a young apple shoot (branch tip) formed by *Tetranychus viennensis*

than those given off in the course of normal transpiration so that the leaves dry up, turn yellow and perish prematurely. The fruits no longer receive their full supply of nutritive substances, with the result that they remain small in size or fall early. Moreover, too few fruit buds are formed.

On a tree heavily infested by hawthorn spider mites, the insects spun dense webs over the leaves extending from the blades to the stalks (Fig. 26), and even from leaf to leaf. On the leaf tips at the end of an annual shoot, the old insects huddled together in thick convolutions to form groups the size of a pin-head.

Observations conducted on hawthorn spider mites which had grown on preparations, showed that the entire body, hairs and legs were covered by

spores of different fungi (scab — *Venturia inaequalis*, powdery mildew — *Podosphaera leucotricha*, and sooty moulds). From this it is concluded that the spider mites also play an active part in the spreading of fungi.

### C. Plant hosts

The literature does not contain very many reports on the occurrence of *T. viennensis*. Zacher (1920) quotes the following plant hosts to this spider mite species: pear *(Pirus communis)*, apple *(Pirus malus)* and heart cherry *(Prunus avium* var. *Juliana* D. O.), also wild cherry *(Prunus cerasis)*, sloe *(Prunus spinosa)*, rowan tree *(Sorbus)*, hawthorn *(Crataegus)* and lime *(Tilia)*. Hirst (1920) refers to hawthorn hedges *(Crataegus spec.*, probably *Crataegus oxyacantha)* as plant hosts. Chaboussou and Bessard (1954) mention stone fruit and apples as the plant hosts for the South of France, and pears for the region around Paris. Rambier (1954) quotes fruit trees, in particular apple trees. Massee (1943) gives the Aylesbury damson as a plant host, and states that the hawthorn spider mite has been found in large numbers on this variety in England.

During my own studies, *T. viennensis* was found on the following plant species in the winter of 1953/54 in the Botanical Gardens of the Agricultural College at Stuttgart-Hohenheim:

1. *Crataegus azarolus* L. — slight infestation.
2. *Crataegus grandiflorus* C. Koch — slight infestation.
3. *Crataegus monogyna* Jacq. — slight infestation.
4. *Malus floribunda* Siebold — odd cases of infestation.
5. *Malus pumilla* Mill. *var paradisiaca* Schneid. (Med.) — odd cases of infestation.
6. *Malus sylvestris* Miller — slight infestation.
7. *Malus sieboldii* Rehd. — slight infestation.
8. *Pirus pollveria* L. — Bollweiler pear, odd cases of infestation.
9. *Prunus cerasifera* Ehrh. — serious infestation.
10. *Sorbus intermedia* Pers. *(S. scandica* Pries) — slight infestation.

In the vicinity of Stuttgart-Hohenheim and Nürtingen/Neckar, the hawthorn spider mite was found chiefly on fruit trees, namely apples, pears and stone fruit (damsons, plums, yellow plums [mirabelle] and peaches), but never on cherry trees. There is every indication that the mite shows preference for a certain variety among apples. For example, in neglected orchards where in addition to "Goldparmäne", "Thüringer Winterrambour", "Transparent" and undefined varieties, "Bohnapfel" apples were chiefly grown, serious infestation was established only on the last-mentioned variety. There was also slight infestation on "Goldparmäne". It cannot, however, be said whether the "Bohnapfel" variety, in particular, offers the hawthorn spider mite better nutrition or whether the leaves of the variety are colonized more frequently than others because they have less hair on them.

In tests conducted on potted plants, it was evident that the mites showed a preference for leaves without hairs rather than those with hairs.

In order to establish whether *T. viennensis* settles on weeds or meadow flora before colonizing a fruit tree, tests were conducted in which various weeds and meadow plants were colonized with mites. A further object of the

tests was to establish whether the mites can take food or build up a population on these different plants.

Leaves of the following useful plants and weeds were used: White clover *(Trifolium repens), Dactylus glomerata,* milfoil *(Achielleum millefolium),* dandelion *(Taraxacum officinale),* groundsel *(Senecio vulgaris),* rose *(Rosa dumentorum),* bramble *(Rubus fructicosus)* and strawberry *(Fragaria* spec.).

The leaves were kept in thermostats at a temperature of approximately 23 ° C. It was found that all winter females died on all leaves of the above-mentioned plants within ten days at the latest. It was first noticed that the mites moved around on the leaves in a most lively manner. No cases were observed of the mites sucking on the leaves, nor were any traces of feeding found, such as punctures in the leaf epidermis or excrement.

When the test was repeated in Summer, no positive results were obtained with summer females, either. The insects could not be compelled to take food on the test plants.

It may be said with certainty that the hawthorn spider mite never lives on the flora growing underneath a fruit tree nor migrates from such plants to the fruit tree but is always to be found only on fruit trees or related trees and plants.

When the mites were transferred from *Prunus* to *Pirus* and vice-versa, no indications were given of a stimulation in development, as compared with the results obtained from the apple series. The ovipositional, pre-ovipositional and post-ovipositional periods, the number of eggs laid per female, the embryonic development, the development of the different stages and also the entire life-period of the mites conformed with the values obtained for the apple series.

In the same manner, summer females were transferred from a stonefruit tree (plum) to apple leaves. Here too, no differences were established in the development data of the mites. From this, it may be concluded that the hawthorn spider mite reacts indifferently towards plants of the *Pirus* and *Prunus* groups, in other words that it has adapted itself to these plants.

### D. Geographical propagation

It is to be assumed that the propagation area of the hawthorn spider mite is more extensive than previously known. It has not been until recently that more reports have been published on the occurrence of this species.

Z a c h e r (1949) stated that the species was found in Vienna (Institute for Plant Protection) and Berlin-Dahlem. H i r s t (1920) discovered the species near Salisbury, Wilts (England). G e i j s k e s (1939) drew an illustration of the hawthorn spider mite from a specimen found in Sweden (Kristinehamm) on a lime-tree. R o e s l e r (1953) and D o s s e (1953) had their attention drawn to this species after an exceedingly large population developed in 1946 and 1947, two years favourable for the development of spider mites. R o e s l e r (1953) first noticed the winter females present in dense groups in trap belts set to catch fruit maggots. He assumes that the species is rather evenly spread in the Pfalz.

For the purpose of my own studies, untreated orchards were investigated in the vicinity of Stuttgart-Hohenheim and in the district of Nürtingen/Neckar.

In both areas, *T. viennensis* were found at all times. In the orchards at the foot of the Hohenneuffen near Neuffen, the trees were very seriously infested by the hawthorn spider mite, whereas on the slope of the hill it was found that colonization decreased proportional to the height. On the upper Alpine pasture near Erkenbrechtsweiler (height of approx. 750 metres), the rate of infestation, however, was again the same as that observed in the plains.

The following places where *T. viennensis* was also found in untreated apple orchards in Baden-Württemberg, are listed in the records of Dosse: Aalen, Adelsberg (Schurwald), Biberach, Calmbach, Calw, Lauffen/Neckar, Maulbronn, Teinach (Calw), Simmerfeld (height of 700 metres), Weingarten and Würzach (Ulm).

The spider mite is a native of Europe. Chaboussou and Bessard (1954) and also Rambier (1954) report on the occurrence of this species with increasing frequency in France, and quote the South of France and the region around Paris as the propagation areas. Ugarov and Nikolski (1937) described its occurrence in Russia. Nothing is known of the incidence of the hawthorn spider mite in oversea countries.

### E. Possibilities of propagation (wind, spreading of mites)

The building up and the expansion of a spider mite population on a fruit tree is chiefly carried out by the female imagines. After mating, they search for new feeding places, and migrate from their original leaf in the direction of the tip of the bough or branch. Deutonymphs also display an urge to migrate, and change over to new leaves where there is more food than on the original leaf. Due to their own movements, the spider mites are themselves responsible for their propagation on a tree.

Propagation over larger distances leading to the colonization of a neighbouring tree, may also be effected as the result of active motion by the mites. It was observed that winter females of the hawthorn spider mite species climbed down from the tip of a 30 cm long water shoot to the base in $1^1/_2$ minutes. In Spring, too, the winter females are very mobile. They were seen to wander from the bark (winter quarter) of a main bough to the tip of a shoot (fruit wood) in only a few minutes, and then colonized the leaves.

Despite the fact that this species is able to move about considerably on its own, propagation over large distances must also be attributed largely to passive forms of movement, in particular the drifting of spider mites by the wind. Unterstenhöfer (1953) dealt with the question of the occurrence of epidemiologically important plant hosts to *B. praetiosa* Koch, *M. ulmi*, and *T. althaeae* v. Hanst. *(urticae* Koch). He mentions a number of shrubs, particularly belonging to the group of Rosaceae, which serve as food plants for *M. ulmi* and *B. praetiosa*. He arrives at the conclusion that when these food plants are growing in the immediate vicinity of an orchard, infestation can spread from them to the trees in the orchard due to the mites being carried by the wind. As the hawthorn spider mite almost exclusively colonizes plants belonging to the group of Rosaceae, it is also possible for this species to migrate from neighbouring plant hosts into orchards.

In order to establish whether the hawthorn spider mite is carried by the wind, tests analogous to those conducted by Andersen (1947), were carried

out in a seriously infested orchard in Stuttgart-Plieningen. The test method corresponded to that used by Andersen (1947). In addition to plates laid out vertically, others were used placed in a horizontal position. The velocity of the wind and the wind direction were not established. Glass plates (10×10 cm) coated with vaseline, were laid out in the orchard for a period of five days and for one of eight days (Fig. 27). The numbers caught were checked by means of a binocular lens.

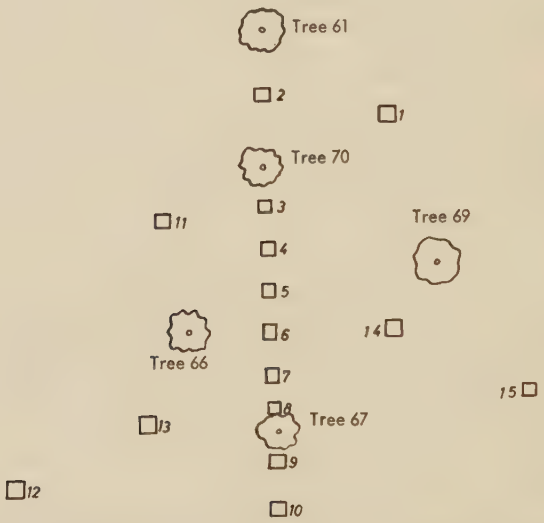


Fig. 27: Distribution of glass plates (10×10 cm) in an orchard in Stuttgart-Plieningen, to establish the drifting of hawthorn spider mites with the wind

During the first test, neither juvenile stages nor imagines of the hawthorn spider mite drifted onto the glass plates. In the second test when certain of the leaves had already started to fall, eggs, larvae and nymphal stages were found, also females but no males. The female mites found were all winter females. In comparison with the tests conducted by Andersen (1947), it is evident that the hawthorn spider mite settles on the leaves far more firmly than *M. ulmi*. Presumably, this is to be attributed to the spinning activities of *T. viennensis*. The web of the hawthorn spider mite offers it excellent protection against falling and being carried away by the wind.

The differences between test a) and test b) are also probably of significance.

With the exception of the row headed "No. per sq. metre/day", the figures give the sum totals of stages or insects found per plate in each case. Non-defined species were placed together under the heading "Other mites". Those plates not included in the table had no mites on them.

No spider mites were caught in test a) which was carried out in the middle of August. The mites were still firmly seated on the leaves. In test b) which was started about four weeks later than test a), the first leaves began

*Table 15:* Propagation of the hawthorn spider mite *(T. viennensis)* by the wind.
a) test started on August 12, 1953
b) test started on September 10, 1953

| Test a | | | | | | | | | Test b | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plate No. | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 1 | 4 | 5 | 6 | 9 | 11 | 12 | 13 | 15 |
| *T. viennensis* | | | | | | | | | | | | | | | | | |
| Eggs | — | — | — | — | — | — | — | — | — | 1 | — | — | — | — | — | 1 | 2 |
| Larvae | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 1 | — | — |
| Protonymphs | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| Deutonymphs | — | — | — | — | — | — | — | — | 1 | 2 | — | — | — | — | — | — | 1 |
| Females | — | — | — | — | — | — | — | — | — | 2 | — | 2 | 1 | — | — | 1 | — |
| Males | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| No. per sq. metre/day | — | — | — | — | — | — | — | — | 12 | 62 | — | 25 | 12 | — | 12 | 25 | 37 |
| *Metatretanychus ulmi* | — | — | — | — | — | — | 7 | 1 | 1 | — | — | — | 1 | 1 | — | — | — |
| *Bryobia praetiosa* | — | — | — | 2 | — | — | — | 2 | — | — | — | — | — | 1 | 1 | 1 | 1 |
| Other mites | 1 | 2 | 2 | — | 4 | 4 | 1 | — | 1 | 3 | 1 | 3 | 3 | 1 | — | — | 1 |

to fall, and drifted eggs, juvenile stages and imagines were counted on the plates that had been set out. From this it may be concluded that the hawthorn spider mite is securely settled on the leaves until the beginning of Autumn, and does not propagate until the first fall of leaves (Table 15).

As the mites are of slight weight and due to their many long extremities and covering of tactiles offer the wind a good surface of attack, they are transported over long distances when the velocity of the wind is high. Plate No. 15 which was set out on September 10, 1953, was covered with a relatively large number of stages despite the fact that it was located 6 metres away from the nearest tree.

On the other hand, the mites can hardly be propagated over large distances with the help of the wind. Man also contributes towards propagation. For example, the shipment of young trees which are colonized by only a small number of winter females of the hawthorn spider mite, can lead to the infestation of an area which previously had not been attacked. Although there are few possibilities for winter females to go into hiding on noble scions, theoretically it is feasible for propagation to be effected by grafted scions.

## V. Control

### A. In Winter

In order to examine what effect a winter spray application has upon the colony of hawthorn spider mite females on a fruit tree, seriously infested old apple trees growing in an untreated orchard near Stuttgart-Birkach were treated on March 16, 1954, with several winter sprays. The female population

was checked before the application. For each tree, approximately 15 winter quarters were counted in the laboratory under the binocular lens, and the natural mortality rate of the winter females was determined on the date of the treatment (Table 16).

It was established that the average natural mortality rate amounted to 30 % of the number of females originally present.

*Table 16:* Population of winter females of *T. viennensis* on trees in an untreated orchard near Stuttgart-Birkach (March 1954).

| Tree No. | Total | Living | Dead | Living % | Dead % |
|---|---|---|---|---|---|
| 1 | 72 | 48 | 24 | 67 | 33 |
| 2 | 65 | 47 | 18 | 72 | 28 |
| 3 | 71 | 51 | 20 | 72 | 28 |
| 4 | 84 | 56 | 28 | 67 | 33 |
| 5 | 45 | 33 | 12 | 73 | 27 |
| 1 — 5 | 337 | 235 | 102 | 70 | 30 |

The following winter sprays were applied at the given concentrations:

1. From the group of nitrophenol (yellow spray DNC 0·75 %).
2. From the group of mineral oils with additives:
   a) with dinitrocresol (yellow oils 4 %),
   b) with heavy oil (carbolineum oils 4 %).
3. As additive to 2 a) and 2 b) HCH spray (Hexa) tech.: 0·5 %.

Each tree was completely wetted with spray so that excess spray wash dripped. The weather on the date of spraying was warm with an overclouded sky and a light wind (0·5 to 1 metre/second). A parallel test was conducted in an orchard at Plieningen, using the same preparations. In this test, the weather on the date of spraying was fair, sunny and only slightly windy (approx. 1 metre per second). The results were checked in Birkach on April 27, 1954, and in Plieningen on April 28, 1954.

Although a winter control of the hawthorn spider mite only has a theoretical value because the insects in their winter hiding places very seldom come into direct contact with the pesticide, a knock-down amounting to over 80 % was nevertheless recorded in both test series (Table 17). This result, however, is deceptive because allowance must also be given for the natural mortality of the mites (30 %). This would then give a knock-down rate averaging 50 %.

No considerable differences were established between the preparations of group 2 and their combinations with HCH (group 3). In both test series, it was found that the knock-down percentages given by carbolineum oil were slightly higher than those recorded for a combination of carbolineum oil and technical HCH. With respect to the combination of yellow oil and technical HCH, it appears as if a slight increase in the knock-down percentage is obtained by using the additive.

The remaining 15 to 20 % of the female population originally present in the winter quarters, which survived, are sufficient to build up in the following year a population just as large as in the preceding year. Consequently, even a thoroughly conducted winter spray application will not give a fully successful control.

With regard to the winter spray trials, it should also be mentioned that the majority of mites which had sought winter quarters in lichens, were killed by all preparations even when they did not come into direct contact with them. Mites which overwintered under bark scales were less exposed to the effect of the poison, and the largest number of insects that survived were found under pieces of bark.

*Table 17:* Results of winter spray applied against *Tetranychus viennensis.*
a) Orchard in Stuttgart-Birkach; sprayed on March 16, 1954,
b) Orchard in Stuttgart-Plieningen, sprayed on March 17, 1954.

| Tree No. | Preparation | Concentration % | Total No. of winter females | Dead % |
|---|---|---|---|---|
| a) | | | | |
| 1 | DNC | 0·75 | 202 | 82 |
| 2 | Yellow oil | 4·0 | 199 | 86 |
| 3 | Yellow oil and HCH tech. | 4·0<br>0·5 | 215 | 91 |
| 4 | Carbolineum oil | 4·0 | 234 | 90 |
| 5 | Carbolineum oil and HCH tech. | 4·0<br>0·5 | 164 | 96 |
| b) | | | | |
| 61, 62, 70 | DNC | 0·75 | 260 | 80 |
| 66, 67 | Yellow oil | 4·0 | 252 | 85 |
| 68, 69 | Yellow oil and HCH tech. | 4·0<br>0·5 | 189 | 88 |
| 63, 64, 65 | Carbolineum oil | 4·0 | 217 | 85 |
| 71, 73, 74 | Carbolineum oil and HCH tech. | 4·0<br>0·5 | 275 | 80 |

### B. In Summer

The Summer trial controls were conducted in 1955 outdoors on potted apple bush trees. Once the trees had grown sufficient foliage, they were colonized with outdoor specimens of the hawthorn spider mite. Although the bush trees were not well protected against the weather, a large mite population developed rapidly, and the treatment was carried out on June 6, 1955.

As no measures have previously been recommended in the literature for controlling the hawthorn spider mite, use was made of the main groups of insecticides and acaricides considered suitable for a control.

The following preparations were applied at the given concentrations:

1. From the group of phosphoric esters:
   "E 605" conc. at 0·035 %.
2. From the group of systemic insecticides:
   "Systox" at 0·05 %.
3. A barium polysulphide spray from the group of sulphur-containing fungicides:
   "Solbar" at 1 %.

The trial controls were carried out in two plots, each group being sprayed with all preparations. The two groups were only counted once, the first on June 13/14, and the second about a week later on June 22/23, 1955.

In the count it appeared advisable to form different evaluation groups. Larvae and nymphal stages were placed in the group called "juvenile stages", and the first to third quiescent stages in the group referred to as "quiescent stages". Eggs and imagines were placed in separate groups of their own. No record was kept of the development stage of the eggs when they died.

The percentages of living and dead mites were only calculated within the above groups. 500 to 1000 eggs and stages were evaluated per preparation (Table 18).

*Table 18:* Summer control of *Tetranychus viennensis* with different insecticides and acaricides.
Treatment: June 6, 1955; 2 groups treated.
1st group counted on June 13/14, 1955,
2nd group counted on June 22/23, 1955.
Mortality expressed in percentage.

| | "E 605" conc. 0·035 % | "Systox" 0·05 % | "Solbar" 1·0 % | Untreated |
|---|---|---|---|---|
| 1st count | | | | |
| Eggs | 53 | 9 | 3 | 0 |
| Juvenile stages | 91 | 98 | 72 | 1 |
| Quiescent stages | 50 | 10 | 0 | 0 |
| Imagines | 94 | 79 | 22 | 11 |
| 2nd count | | | | |
| Eggs | 97 | 64 | 16 | 2 |
| Juvenile stages | 91 | 96 | 58 | 3 |
| Quiescent stages | 57 | 38 | 11 | 2 |
| Imagines | 78 | 77 | 41 | 10 |

"E 605" conc.

In comparison with the first count, the knock-down percentages recorded in the second count increased for all groups with the exception of the imagines. In the first count, an egg mortality of 53 % was established. The mortality of the juvenile stages was determined at 91 %, for the quiescent stages at 50 %, and for the imagines at 94 %. The second count gave a mortality quota of 97 % for the eggs, 91 % for the juvenile stages, and 57 and 78 % for the quiescent stages and imagines, respectively. Most striking is the very high percentage of dead eggs and quiescent stages. From this it may be concluded that "E 605" acts on the eggs of the hawthorn spider mite. On the other hand "E 605" does not appear to penetrate the integument of the quiescent stages so well as it does through the skins of the eggs. 50 % of the quiescent stages were found to be dead in the first count, and 57 % in the second count. A part of the quiescent stages emerged following the first count. Imagines developed which were evaluated in the second count thus reducing the percentage of imaginal mortality (Table 18).

As the larvae and juvenile stages, in particular, reacted well to "E 605" conc. in this test, it may be concluded that the preparation has a pronounced ovo-larvicidal action.

"Systox"

"Systox" has a good action against the juvenile stages and the imagines. The quiescent stages are most resistant, just as to "E 605" conc.

The first count showed the mortality rate in the juvenile stages to be 98 %, 10 % in the quiescent stages and 79 % among the imagines. In the second count, the corresponding values recorded were 96 %, 38 % and 77 % (Table 18).

In comparison with "E 605" conc., "Systox" is less effective against the hawthorn spider mite.

"Solbar"

The effect of "Solbar" against the hawthorn spider mite is unsatisfactory. The stages most susceptible to "Solbar" are the juveniles. The slightest reaction is shown by the eggs, and the quiescent stages are also most resistant (Table 18).

### C. Results and conclusions drawn from the trial controls

The results may be summarized as follows:

1. The winter sprays with carbolineum oils and additions of DNC eradicate a large percentage of overwintering females. But this does not prevent those females which survive from rebuilding a population between Spring and the end of the vegetation period, the size of which depends upon the weather conditions prevailing during the course of the year.
2. The Summer applications with phosphate preparations promise to give an effective control of an existing mite population.

3. The trial controls were first carried out in Summer. Just the same, it can be said that the best time for carrying out a control of the hawthorn spider mite, making allowance for the biological development, is at the beginning of the vegetation period.

The control of a spider mite population is all the more difficult, the greater the population has developed in the course of the year. In order to bring about a perceptible decimation of a population of hawthorn spider mites, it is commendable to carry out a winter control with one of the conventional winter sprays, preferably a carbolineum oil or mineral oil mixed with DNC. Making allowance for the biological reaction of the hawthorn spider mite, the main control should be carried out as soon as the winter females emerge from their winter hiding places. This is best done in combination with the usual preblossom spray applications by adding a specific acaricide or a phosphoric ester. Consequently a single operation will combine several sprays, the control of Fusicladium and, when ester preparations are applied, also the eradication of winter moth, apple blossom weevils, aphids and finally spider mites.

From the technical aspect of the control, particular importance should be attached to the thoroughness with which the sprays are applied. As the spider mites chiefly occur on the underside of the leaves, the abaxial surfaces should be given a good coverage of spray wash. If a pre-blossom spray cannot be carried out for technical reasons, a post-blossom spray combining application of the above-mentioned preparations will give the same degree of success.

## VI. Summary

The harmful occurrence of the hawthorn spider mite *(Tetranychus viennensis* Zacher) on deciduous fruits in the vicinity of Stuttgart-Hohenheim led to studies being conducted on the morphology, biology and control of this Tetranychus.

Morphology

The systematic classification is followed by morphological data on the different stages of development.

The females occur in two forms (Winter and Summer females) which do not differ morphologically. Winter females have a bright red colour, and mostly light-yellow to sandy-coloured extremities whereas Summer females are a bluish-violet, shimmering matt carmine-red with light (whitish) segments. The winter female is 0·368 mm long and 0·244 mm broad, while the length and breadth measurements of the summer female are 0·675 mm and 0·411 mm, respectively.

The tactile covering of the extremities (Tarsus and tibia I to IV) is described; four forms of chemosensory setae are mentioned.

Characteristic of the mite is the peritrema, the most important feature for recognition purposes. The terminal branches form compartments of an irregular pattern; a definite shape among these is never to be found.

The male is fully described for the first time. It is a sandy-yellow in colour. Greenish-black spots may be observed under the integument. It is 0·402 mm long, and 0·191 mm broad.

The tactile covering of the male extremities differs from that of the female, and is discussed comparatively. The ambulacrum on the tarsus I of the male is strengthened at the centre apophysis of the three-part claw.

The peritremae are somewhat smaller and their terminal branches are more frequently sub-divided than on the female.

The penis has a long and thinly drawn-out clasper, at the lower base of which a small knot is located.

The colour and form of the different stages of development vary. Sexual dimorphism is recognizable in the deutonymphal stage.

## Biology

The biological studies were conducted on isolated females located on potted apple seedlings under similar environmental conditions.

Only the fertilized females overwinter. When the leaves begin to fall, the insects creep into their winter hiding places under bark scales or mosses and lichens on the boughs and branches of the plant host. Winter quarters in the soil or on the flora growing underneath the fruit trees, were not found. *Eotetranychus pomi* Sepasgosarian and the natural enemies, *Typhlodromus* species and *Mediolata mali* Ewing, were discovered sharing the same winter hiding place with *T. viennensis*.

In the vicinity of Stuttgart-Hohenheim, the mites emerge from their winter hiding places at the earliest towards the end of March, when the mean daily temperatures are between 9 and 10 ° C. The main period of migration from the winter quarters is just before the beginning of blossom-time. The young shoots are colonized starting at the lowest leaf. Mostly a leaf is inhabited by only one female.

In the field, the generations already begin to overlap at the start of the second generation. Towards the end of the vegetation period, they increase. Four of five generations may occur. The life-period of a generation becomes longer as the season progresses.

The development periods of the different stages of both sexes do not vary very much. Differences are evident during the course of the year. The period spent by the male in the second nymphal stage and the third quiescent stage is shorter than that recorded for the female. The average calculated for all generations shows that in the field the females take 22 to 23 days to complete their whole development, while the males take about 21 days. The time of development for the different stages in the last generation is almost twice as long as in the first generation.

In the field, the life-cycle of the imagines is 20 to 30 days for females, and 8 to 16 days for males.

There are no differences between winter and summer females with respect to oviposition. Mostly, the eggs are laid on a part of the abaxial surface of the leaf, that is covered by a web. There are always more females present than males. At the end of the vegetation period, there is an increase in the number of females to each male.

The highest rate of mortality is in the egg stage, followed by the larvae, protonymphs and deutonymphs for which the values decrease accordingly. All deutonymphs which enter the third quiescent stage, emerge as imagines.

The factors which determine the occurrence of winter females are lack of food and decreasing temperatures. The change-over to winter females is already recognizable in the second nymphal stage from the brownish-coloured intercalations.

### Epidemiology and ecology

The change in population density for 1954 is discussed.

The injury inflicted by the hawthorn spider mite is characteristic in the initial stage. Yellow spots the size of a pfennig or a hazel-nut are formed on the leaves. Later, the foliage becomes greyish-yellow. The fruits remain small in size. Very few fruit-buds are formed.

The chief plant hosts to *T. viennensis* are Rosaceae, in particular fruit trees (apple, pear and all stone fruit). Transfer tests to meadow plants (fruit meadows) proved unsuccessful.

The geographical propagation is discussed on the basis of data given in the literature. Locations are given where the mite was discovered to occur in Baden-Württemberg. The possibility of propagation by active and passive (wind) movement is examined.

### Control

Following an application of commercial winter sprays (DNC, yellow oil, carbolineum oil), up to 20 % of the winter females survive. Consequently, a winter treatment is not fully effective, and therefore not completely satisfactory.

A summer spray application with phosphoric esters ("E 605" conc., "Systox") ensures absolute success. The effect of "Solbar" against *T. viennensis* is unsatisfactory.

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